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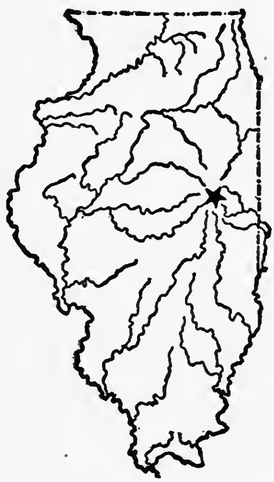
ELECTRIC POWER FOR THE FARM

By E. W. Lehmann and F. C. Kingsley



URBANA, ILLINOIS, JUNE, 1929

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FOREWORD

Farmers will be slow to install electrical equipment and pay for electric energy unless it can be demonstrated that by so doing they can actually save money or that the conveniences and comforts made possible by electricity fully justify the necessary expenditures.

The power companies and even the manufacturers of electrical appliances and equipment may be obliged to market their products at prices which for a time may mean a loss, in order to develop a sufficient volume of business to bring them a reasonable return.

It would be of mutual advantage to all concerned if such rates and policies for supplying electric service were formulated that, in a reasonably short time, an increase in the use of energy and electrical equipment would lower the prices so that farmers could afford to buy and power companies afford to sell.

The Illinois Agricultural Experiment Station recognizing these facts undertook this study and, in line with the policy of the Station, an advisory committee was selected to assist in the investigation. Thru the work of this committee the project on the use of electricity in agriculture was outlined. Funds for carrying out the project were provided by the Illinois State Electric Association. The members of the committee were as follows:

H. W. Mumford, Dean of the College of Agriculture, University of Illinois, (chairman)

E. W. Lehmann, Professor of Farm Mechanics, University of Illinois, (secretary)

H. C. M. Case, Professor of Farm Organization and Management, University of Illinois

J. Paul Clayton, Vice-President, Central Illinois Public Service Company, Springfield, Illinois

Lloyd Yost, Fairbanks-Morse & Company, Beloit, Wisconsin

Bert H. Peck, Illinois Power & Light Corporation, St. Louis, Missouri

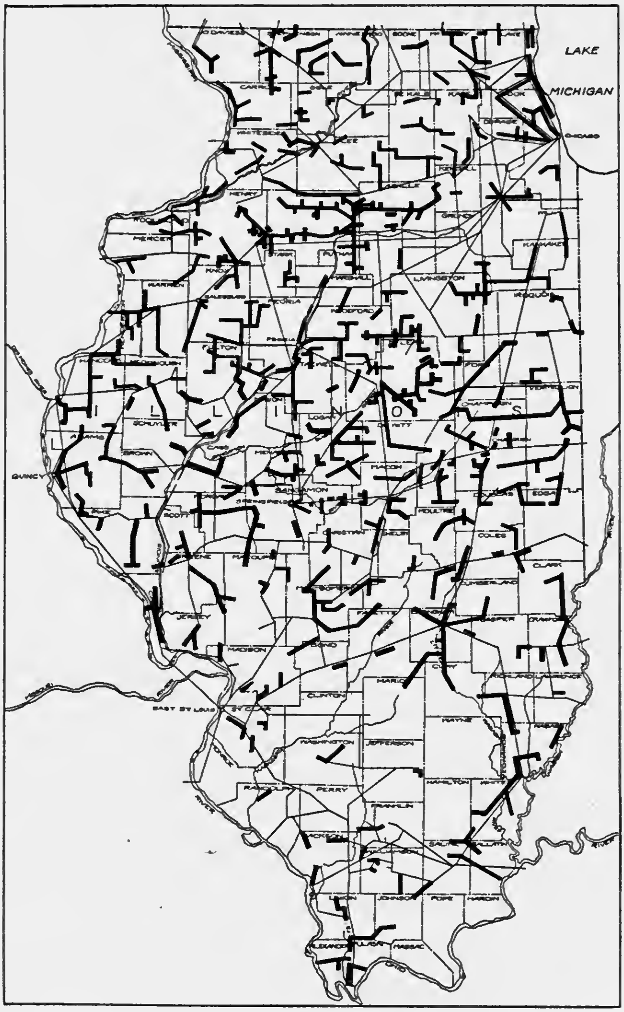
H. E. Worden, Central Illinois Light Company, Peoria, Illinois

Mrs. H. M. Dunlap, farm homemaker, Savoy, Illinois

J. P. Stout, farmer, Chatham, Illinois

H. H. Parke, farmer, Genoa, Illinois

E. A. Eckert, farmer, Mascoutah, Illinois



Electrical Transmission Lines Supplying Current to Farms and Towns, 1928

There are over 9,000 miles of interconnected high voltage lines now built in Illinois. About 4,000 miles of these transmission lines are of sufficiently low voltage so that farmers can obtain current, and the mileage of such lines is being increased rapidly. The above map shows how these lines are distributed over the state. The heavy lines are those from which farmers can get service by the use of a transformer. The light lines are those with voltages from which it is not practical for farmers to get service.

ELECTRIC POWER FOR THE FARM

By E. W. Lehmann and F. C. Kingsley[1]

High voltage distribution lines now extend to practically every section of the state of Illinois. It has approximately 9,200 miles of interconnected lines serving over 1,200 towns and cities. About 4,000 miles of line are of low enough voltage so that farmers may secure service from them, and many of the high-voltage lines are so designed that a lower voltage may be strung on the same towers or poles at a great saving in cost. There are also approximately 1,200 miles of lines built especially for farm service. Thus a network of electric lines offers great possibilities for supplying electricity to Illinois farms and farm homes.

Another source of electricity for the farm is the unit electric plant. Such a plant fills a real need where electricity cannot be secured from a power line. It furnishes adequate energy for lighting, for household appliances, and for minor power up to one horsepower, but it is not adequate for larger power operations or for cooking. The central station plants are much more economical producers of power where large quantities are involved. It holds true in the country as well as in the city that the individual who uses sufficient power so that he can secure service at a reasonable rate from a high-voltage line cannot afford to operate a plant of his own. The results of a study of five unit plants are given in the Appendix on pages 471 to 473.

The problem of supplying power from the central station to the farm is largely one of delivery costs and of getting the customer to make sufficient use of the service to pay both him and the company. Electricity used on farms in the past has been largely for lighting the home. An electric load of this type does not return a direct income to the farmer to offset the expense incurred, nor does it give sufficient return to the utility company to pay for the service.

From surveys made by the University it is apparent that many farmers who have electric power service are failing to use it for the numerous operations to which it is easily adapted. The average energy consumption per farm over the state is very low; on some lines it was found to be less than 30 kilowatt hours a month. At the rates charged, this does not bring in sufficient income to the utility companies to justify them in extending lines to farms and providing transformers and other equipment needed to make satisfactory service possible.

[1]E. W. Lehmann, Chief in Farm Mechanics; and F. C. Kingsley, formerly Assistant in Farm Mechanics. J. C. Bottum, formerly Assistant in Farm Mechanics, assisted with the study during a part of the period and gave special assistance in the preparation of the farm management phase of the manuscript.

The first study (1923) was based on 93 farm homes in Bureau county having electric service. While all 93 homes were lighted with electricity, only 50 percent used electric motors for limited power operations, including pumping, grain grinding, grain elevating, and household operations. Gasoline engines were still being used for power by 27.9 percent and windmills for pumping were used by 53.6 percent. Service from power lines had been available for one to ten years. A later survey (1926) covered several thousand Illinois farms. While all used electricity for lighting, only 75 percent had electric irons, 49 percent electric washers, 28 percent electric vacuum cleaners, 22 percent electrically operated pumps, 12.8 percent toasters, 6.7 percent fans, 6.4 percent power-driven separators, 5.7 percent electric ranges, 3.0 percent motor-driven milkers, and 1.4 percent electric refrigerators. A number of small appliances were being used but they constituted a very small part of the total.

Several factors, therefore, led to the study reported in this bulletin, namely:

1. The desirability of adequate electric service for convenience and comfort in the farm home.
2. The growing demand for electric service on the part of farmers and the consequent need for reliable information concerning the practicability of its use on farms.
3. The availability of electric current to Illinois farms.
4. The desire of the utilities companies to find practicable ways of supplying electric service to farmers.

THE TEST FARMS

Character and Organization

Recognizing the principle that the cost per unit of electricity is dependent upon the number of units used, the first step in this investigation was to determine whether sufficient use of electricity could be made on farms to develop a load that would be economical to the farmer and practicable from the standpoint of the utility company. An experimental line was built and electric service rendered to ten farms. In addition to using electricity for household appliances, steps were taken to electrify all belt-power operations on these ten farms and to develop new economic uses, so far as possible.

All ten farms were occupied by owners, except one, and the operator of this farm rented from his father. Farm 9 was occupied by a retired farmer who rented practically all his land to other farmers in the community, and No. 6 was occupied by a widow whose land was rented. Thus in the group of ten there were eight active farmers. The discussion and data in the tables dealing with the production side of the farms is based on the eight active farms.

The area farmed by the eight active farmers was from 160 to 515 acres. The four smaller farms, Nos. 2, 3, 4, and 8, averaged 190 acres. The four larger farms, Nos. 1, 5, 7, and 10, averaged 400 acres. While all were essentially grain farms, Nos. 2 and 8, con-

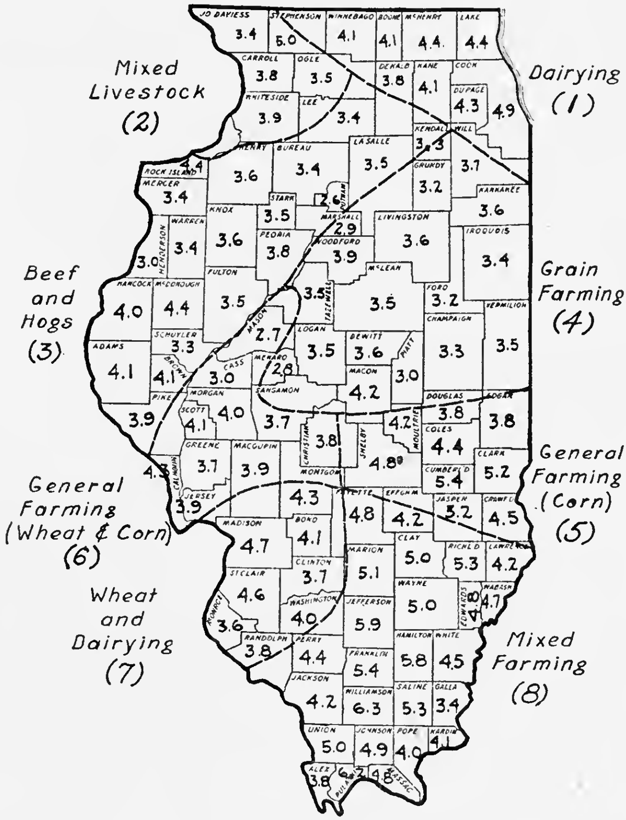


FIG. 1.—FARMING-TYPE AREAS OF ILLINOIS AND NUMBER OF FARMS PER SQUARE MILE IN COUNTIES

In east-central Illinois, where the tests reported in this bulletin were made, there are fewer farms per square mile than in any other section of the state. Corn and oats are the major crops.

sisting of 160 acres each, produced considerable poultry. The other two of the smaller farms, No. 3 with 240 acres and No. 4 with 203 acres, each had a sufficient number of cows to justify the use of an electric milking machine.

Of the group of larger farms, No. 1, consisting of 280 acres, was devoted strictly to grain production. No. 5, 320 acres, differed from

No. 1 in that there was a small income from livestock. No. 7, 480 acres, had a small amount of livestock and specialized in soybeans and seed corn. No. 10, 515 acres, was a representative grain farm with only enough livestock to consume roughages.

The average amount of land farmed by the ten cooperators, including both owned and rented land, was 295 acres, and the average value of each farm was $65,444.

These test farms are located in Champaign county, in the level, fertile, grain-growing section of east-central Illinois, where corn and oats are the major crops and where the larger portion of these crops is marketed directly. It is believed, however, that there were as many representative types of farms on the test line as it would be possible to find in most localities in Illinois.

TABLE 1.—FINANCIAL STATEMENT FOR EIGHT FARMS ON EXPERIMENTAL LINE IN 1926

Items	Average of 4 livestock farms	Average of 4 grain farms	Average of 8 farms
Total capital investment	$52 452	$100 988	$76 720
Land valuation	42 919	87 969	65 444
Total receipts (net increase)	5 712	9 121	7 417
Receipts from feed and grain	3 180	8 282	5 731
Total expense (net decrease)	1 886	3 397	2 641
Receipts less expense	3 826	5 725	4 775
Labor of operator and unpaid family	894	1 306	1 100
Net return on investment	2 932	4 418	3 675
Rate earned	5.6%	4.4%	4.8%

Except for investment in land, the eight active farms had a total average investment that was representative of farms in this section of the state (Table 1). The greater land valuation was due to the larger acreage of the farms and to their higher value per acre. The total investment per farm, including land, varied from $42,526 to $134,282.

The land in these eight farms is practically all tillable. With a total average area per farm of 295 acres, 249 acres were in crops (Table 2). The area in corn ranged from 61 acres on the smallest farm to 226 acres on the largest, averaging 130 acres, or more than 40 percent of the farmed area. Oats, wheat, soybeans, clover, and hay followed corn in order of importance from the standpoint of acreage. Soybeans have been replacing oats to some extent in this locality and have proved a more profitable crop for these farmers than oats because they have been produced and sold as seed.

TABLE 2.—ACREAGES OF CROPS GROWN ON EIGHT COOPERATING FARMS, 1926

Cooperator	1	2	3	4	5	7	8	10	Average of all farms
Corn	148	80	93	84	170	175	61	226	130
Oats	72	14	20	8	35	...	21	136	38
Wheat	30	20	30	12	30	50	10	74	32
Timothy	...	...	...	...	3	...	...	10	2
Clover	...	...	...	3	...	45	18	...	8
Alfalfa	...	4	...	10	...	...	...	...	2
Soybean grain	...	17	37	35	28	85	33	...	29
Soybean hay	...	3	...	...	12	35	7	6	8
Total crop acres	250	138	180	152	278	390	150	452	249
Tillable pasture	20	16	50	45	30	70	3	36	34
Non-tillable pasture	...	...	...	...	...	...	...	23	3
Farmstead, etc	10	6	10	6	12	20	7	4	9
Total acres in farm	280	160	240	203	320	480	160	515	295

Both dairy and beef cattle were kept on these farms. The number of cows varied from 2 to 12 per farm (Table 3). During the three years covered by the study the average number of cows per farm increased. The only representative livestock farm in the group,

TABLE 3.—KIND AND NUMBER OF LIVESTOCK ON EIGHT COOPERATING FARMS, 1926[1]

Cooperator	1	2	3	4	5	7	8	10	Average per farm
Work horses	9	8	12	11	14	11	9	15	11
Other horses	1	...	7	1	3	15	...	...	3
Cows	6	2	7	12	4	8	4	8	6
Other cattle	...	5	17	15	13	10	7	7	9
Sheep	...	...	21	...	...	...	...	...	3
Hogs	2	4	3	30	5	9	12	12	10
Poultry	105	239	12	150	163	120	169	137	137

[1]Inventory taken April 1, 1926.

in the sense that a large proportion of the crops grown on it were fed, was No. 4. Individual farms may be selected from the group that are fairly representative of farming in many other sections of the state. On one the receipts from hogs made up a large share of the income; on the other seven they ranged from $100 to $500 a farm. The number of poultry kept per farm varied from 12 to 239. An increased interest in this enterprise was shown during the period of the study. On two farms it supplied a considerable part of the income.

TABLE 4.—NUMBER IN FAMILY, SIZE OF HOUSE, AND KIND OF EQUIPMENT IN HOUSE OF EACH COOPERATOR BEFORE ELECTRIC POWER WAS MADE AVAILABLE

Cooperator	Average size of family	Type and size of house[1]	Type of heating system	Power washer	Sanitary system	Type of lighting	Water supply
1	7½	2-story 9 rooms	1 soft- and 1 hard-coal stove	Gas engine	Drained sink, outdoor toilet	Kerosene lamps	Kitchen tank
2	2	2-story 7 rooms	2 soft-coal stoves	Gas engine	Drained sink, outdoor toilet	Kerosene lamps	Pump in kitchen
3	8	2-story 10 rooms	1 soft-coal stove	Hand operated[2]	Drained sink, outdoor toilet	Kerosene lamps[2]	Pressure tank in milk house (motor pump)
4	5	2-story 14 rooms	Hot-water furnace	Gas engine	Drained sink, cesspool	Kerosene lamps	2 attic tanks
5	8	2-story 16 rooms	Piped hot air	Gas engine	Drained sink, cesspool	Electric	Pressure tanks in basement
6	2½	1¾ story 6 rooms	2 soft-coal stoves	Hand washboard	Drained sink, outdoor toilet	Kerosene lamps, 1 mantle lamp	Pump in kitchen
7	7	2-story 10 rooms and bath	Pipeless furnace	Gas engine	Drained sink, septic tank	Kerosene lamps	Attic tanks
8	4	2-story 8 rooms	1 soft-coal stove	Gas engine	Drained sink, outdoor toilet	Kerosene lamps, 1 mantle lamp	Kitchen pump only
9	4½	2-story 9 rooms and bath	Hot-water furnace, 1 wood stove	Gas engine	Drained sink, septic tank	Electric	Pressure tank in basement
10	11	2-story 9 rooms and bath	Hot-water furnace	Gas engine	Drained sink, cesspool	Acetylene	Attic tanks

[1]All the houses are frame structures. [2]Electric plant was not in working order.

The average return on the total investment for these eight farms was 4.8 percent in 1926 (Table 1), and for the other two years of the study a similar return was realized. This rate agrees closely with that of a much larger group of farms of the same general area and is nearly 2 percent more than the average farm in this section earned that year.[1]

Preliminary Survey of Equipment and Operation

A complete inventory of all equipment and an analysis of farming operations were made for each cooperating farm before the electric

TABLE 5.—ENERGY USED FOR BELT WORK ON EIGHT COOPERATING FARMS AND PERCENTAGE OF ENERGY SUPPLIED FROM VARIOUS SOURCES, 1926[1]

Operations requiring belt work	Average energy per operation	Part of total energy	Energy provided by various sources
	hp. hrs.	*perct.*	*perct.*
Threshing	425	17.4	Steam engine...20.3
Shredding	70	2.9	
Filling silo	117	4.8	Gas tractor....22.9
Shelling corn	276	11.2	
Grinding feed	168	6.9	
Baling straw	34	1.4	Gas engine, 10 hp....... 1.4
Pumping water	359	14.6	Windmills.....14.6
Grinding feed and miscellaneous	217	8.8	Electricity.....40.8
Pumping water	44	1.8	
Cream separating Washing Operating water system	82	3.3	
Milking	84	3.3	
Operating refrigerator	579	23.6	
Total	2 455	100.0	.............100.0

[1]All units of energy were converted into horsepower hours and averaged for the eight cooperating farms in order to obtain a total of the energy requirements for this type of work on a representative farm.

power line was built. The finished survey gave a complete picture of each farm, showing living conditions, how the farm and household work was done, and the economic status of the farm (Tables 1, 4 and 6). Each job and the equipment available for it were listed, together with the methods used and the time required to do it.

[1]This is shown by studies made by the Department of Farm Organization and Management. The rate earned is calculated after deducting from the total net income wages for the operator and his family equivalent to those of hired labor.

TABLE 6.—CONNECTED ELECTRICAL LOAD, AND AVERAGE ENERGY CONSUMPTION ON EIGHT COOPERATING FARMS, 1925–28

Cooperator	Number in family	Size of farm	Area in crops	Source of income			Total connected electrical load[1]			Transformer sizes 1927-28	Average monthly energy consumption for three years		
				Grain	Livestock	Misc.	1925-26	1926-27	1927-28		1925-26[2]	1926-27	1927-28[3]
		acres	*acres*	*perct.*	*perct.*	*perct.*	*kw.*	*kw.*	*kw.*	*kw.*	*kw. hrs.*	*kw. hrs.*	*kw. hrs.*
1.	7½	280	250	88	11	1	15.998	5.824	5.976	3	407	48	43
2.	2	160	138	58	40	2	14.266	14.266	16.101	5[4]	204	176	251
3.	8	240	180	63	35	2	11.972	7.640	7.950	3	135	107	132
4.	5	203	152	44	56	. .	8.862	7.026	8.301	3	113	109	170
5.	8	320	278	89	11	. .	20.768	16.958	17.082	5[4]	416	209	131
7.	7	480	390	90	9	1	20.662	8.330	15.830	3	448	93	132
8.	4	160	150	61	39	. .	14.413	6.163	5.633	3	228	50	58
10.	11	515	452	94	6	. .	18.617	14.657	12.995	3	589	312	250
Average. . . .	6½	295	249	77	22	1	15.695	10.108	11.234	5[4]	317	138	146

[1]The connected load was determined by taking the sum of the wattage of all lamps, motors, and appliances in use. [2]Energy was furnished free to the cooperators in 1925-26. [3]Average for eight months. [4]Altho a 5-kilowatt transformer was used on three farms, one of 3 kilowatts is large enough.

Stationary gas engines and tractors were quite generally used in the operations listed in Table 5. Three of the farms had small unit electric plants before the electric service was obtained from the power line, the power from these unit plants being used mainly for lights and for very small motors.

On the basis of this preliminary survey the possibilities of substituting electric for other types of power in use on the farms were studied and plans made to use it wherever it seemed practicable.

CONSTRUCTION OF THE EXPERIMENTAL LINE

Since good electric service was essential to the conduct of the investigation, the extension line carrying the power to these test farms was itself in no way an experiment. No expense was spared in its building to insure first-class service. High-class standard construction

FIG. 2.—THE EXPERIMENTAL LINE, SHOWING CONSTRUCTION AT A CORNER

A well-built line, of standard construction, free from tree interference and carefully maintained is essential for continuous service.

was used. Thirty-foot Western red cedar poles, with 7-inch top and 3/8-inch Pentrex treated, were used and were spaced at a maximum of 175 feet. The line was 6600-volt, 3-phase, 3-wire, 60-cycle, and built of No. 4 bare hard-drawn copper, and the minimum spacing between wires was 14½ inches. It was no doubt better than most rural lines.

The question of character of line has been involved only to a limited extent in the problem of furnishing electric service to farmers. It is physically possible to build almost any type or voltage of line. The cheaper constructions, however, are not necessarily the cheapest for the farmers in the long run, for depreciation and maintenance may more than offset the advantage gained with a better standard of line.

The construction used for the experimental line was of considerably higher standard than necessary. In fact the standards that have been generally used for rural service have been higher than necessary. This fact has been recognized by the Illinois Commerce Commission, which in its general order No. 115 reduced the standards it had previously set for rural lines. One public service company serving a large number of farmers in Illinois has filed with the Commission specifications which take full advantage of the new order. With the lower height of pole that is permitted and a longer span construction, the cost of extending rural lines that have fair right-of-way conditions is in the neighborhood of a thousand dollars a mile exclusive of transformers. With an average of three customers to a mile, transformer installation costs would bring the average mile cost up to $1,350.

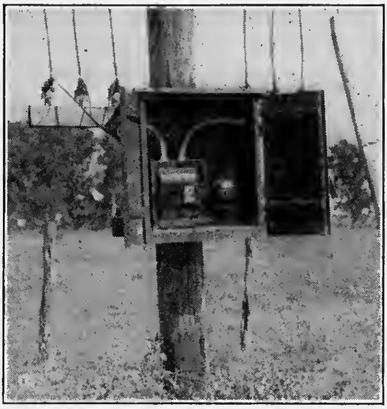


FIG. 3.—TOTALIZING METER AND SWITCHBOX IN BOX ON TRANSFORMER POLE

It is desirable to place the master switch and totalizing meter on the transformer pole for convenience, economy, and safety in providing adequate service leads to the different buildings.

Location and Size of Transformer

The location of the transformer is of importance in relation to the distribution of power about the farm. On the experimental line each transformer was placed reasonably close to the house and the outbuildings in order to have it as near the center of load distribution as possible. A master meter and a switch box were located on the transformer pole. This position is of decided advantage when service is rendered thru one meter. The meter should be readily accessible from the ground and yet high enough so that children cannot reach it.

From 3- to 10-K.V.A. transformers were originally installed on the experimental line. Three- and 5-K.V.A. transformers were later substituted for the larger ones. The best size to use depends upon the total connected load and upon the maximum amount of current required at any one time. The smallest size which will meet the requirements of the customer results in the greatest economy in operation, for the smaller the transformer, the smaller is the core loss.

Table 6 shows the total connected load and the sizes of the transformers that were ultimately used on the cooperating farms,

Wiring the Farmstead and Buildings

An adequate and convenient wiring system, with plenty of outlets properly placed for connecting electrical devices, is the first step toward the satisfactory use of electricity on the farm. Too much emphasis cannot be placed on the importance of this point. To get switches and outlets most conveniently placed for service in the outbuildings as well as in the house require careful thought.

Wiring for both 110- and 220-volt service was provided at each farm. Power outlets for 220 volts, for connecting a portable 5-horsepower motor and other smaller motors by plugging in, were provided at a number of convenient points about each farmstead. One or more yard lights controlled from at least two points were installed. In each house floor and wall outlets were provided for connecting special lamps, vacuum sweepers, and other appliances. The wiring plans for the ten farms were developed from floor plans of the residences and ground plans of the farmstead.

Adequate provision for future connections was made. Too often consideration of future needs is neglected and when a range or a motor of several horsepower capacity is purchased, it is found that the entrance wires or service drops and the wires leading to the meter are too small and larger ones must be put in at considerable expense before the new equipment can be used. The total expense of wiring a house may be greatly reduced by making the original wiring complete and of adequate size to take care of future needs. The saving made by using smaller than No. 6 wire for entrance wires is hardly justified. Care should also be observed to see that the method of wiring is standard practice and that it meets the requirements of the National Board of Fire Underwriters.

Cost of Wiring

The cost of wiring a farmstead depends largely upon local conditions since labor is a big item. To economize by using inexperienced wiremen may prove costly in the end. On the experimental line an experienced wireman was obtained who allowed the farmers to help in their spare time in doing certain phases of the work.

The cost of wiring these test farms, including the cost of hired labor, ranged from $94.66 for a seven-room house, corncrib, poultry house, and one other small building, to $198.74 for a fourteen-room house, barn, corncrib, garage, milk house, and one or two other small buildings. The fixtures cost $79.10 and $191.56 respectively for these same houses. The average cost per farm for wiring was $130 and for fixtures $134, a total of $264 per farm with the houses averaging nine rooms.

The cost per outlet, including wall sockets, outlets for fixtures, etc., ranged from $2.90 to $4.60 and averaged $3.50. A lighting cluster was considered as one outlet. The total number of outlets per farm

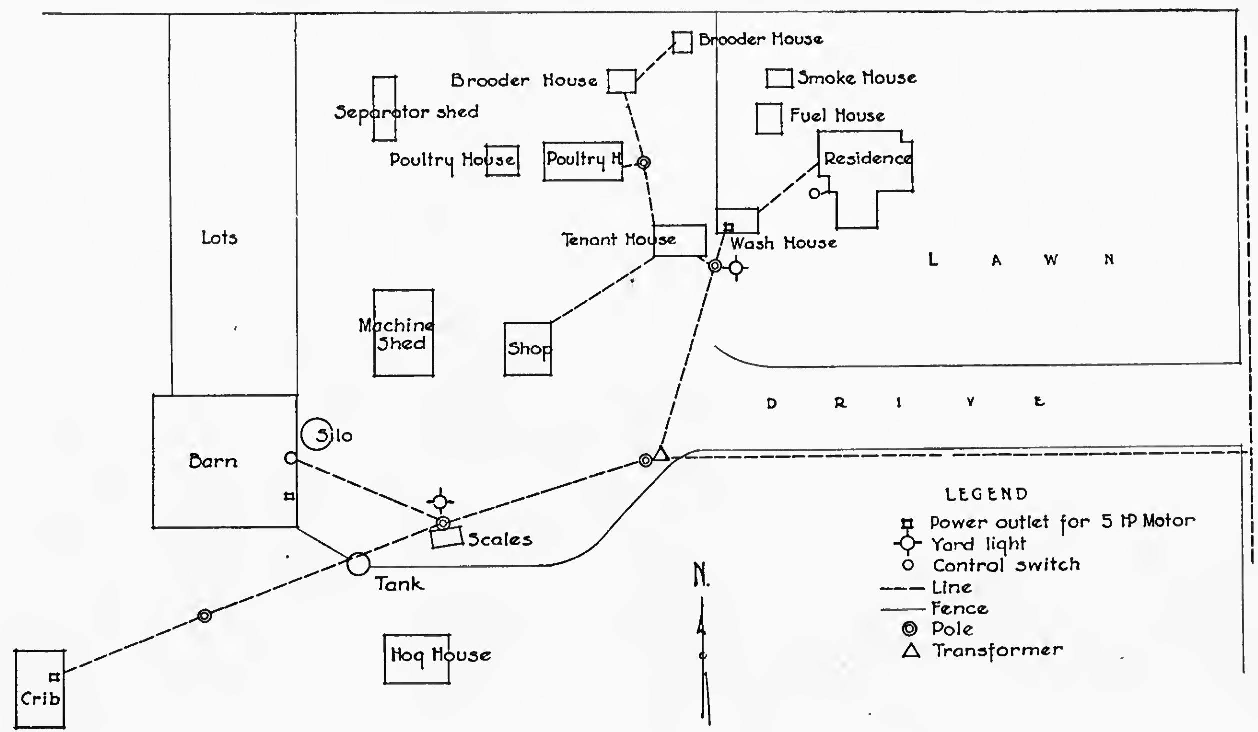


FIG. 4.—PLAN OF FARMSTEAD AND WIRING LAYOUT OF COOPERATOR 4

This was a typical arrangement of wiring and transformer on the experimental farms. A centrally located transformer is necessary for satisfactory power distribution.

ranged from 21 to 49, averaging 37. For outbuildings the average number was 10.

The wiring cost of power outlets was not included in the above, since the experimental work required more outlets than would ordinarily be employed and a record of their cost would therefore be of little practical value.

ENERGY CONSUMPTION ON EACH FARM

The energy consumption on each farm for a period of 32 consecutive months is shown in Figs. 5 and 6, and the total for the ten test farms for 48 months is shown in Fig. 7.

During the first twelve months all energy except that used on the lighting circuit was furnished the cooperators without charge. The equipment was installed on a loan basis. The installation of some of the equipment used during the first year was purely for experimental purposes, it being recognized that it was likely to be impractical. Naturally the use of it during these twelve months made energy consumption high.

With the beginning of the second twelve-month period the farmers were charged the regular rate for all energy used, and all the equipment that had been installed on the loan basis was either removed or purchased. A decrease in energy consumption resulted, but the decrease was due more largely to the removal of equipment than to a reduction in the use of the equipment that was kept.

From the time the above adjustment was made to the end of the test, the energy consumption increased on nearly all farms. The increase was especially marked during the spring months of 1928, when a number of incubators and brooders were bought by the farmers. In every case this equipment was purchased on the initiative of the cooperators, no effort or inducement being offered by those in charge of the investigation to lead them to increase their electrical equipment.

The number of persons in the families of the various cooperators, the size of the farm, the crop acres, the source of income, the connected load, and the average monthly energy consumption for each of the cooperating farms are indicated in Table 6. The effect of the increase in the connected load in 1927-28 on Farms 2, 4, and 7 is reflected in the increased energy consumption during that year.

The summary of data in Table 6 does not show any relation between the size or type of farm or the principal source of income and the amount of electric energy used. Cooperator 2, farming 160 acres, with 40 percent of his income from livestock, used an average of 251 kilowatt hours each month in 1927-28 and Cooperator 8, also farming 160 acres, with 39 percent of his income from livestock, used an average of 58 kilowatt hours a month in 1927-28.

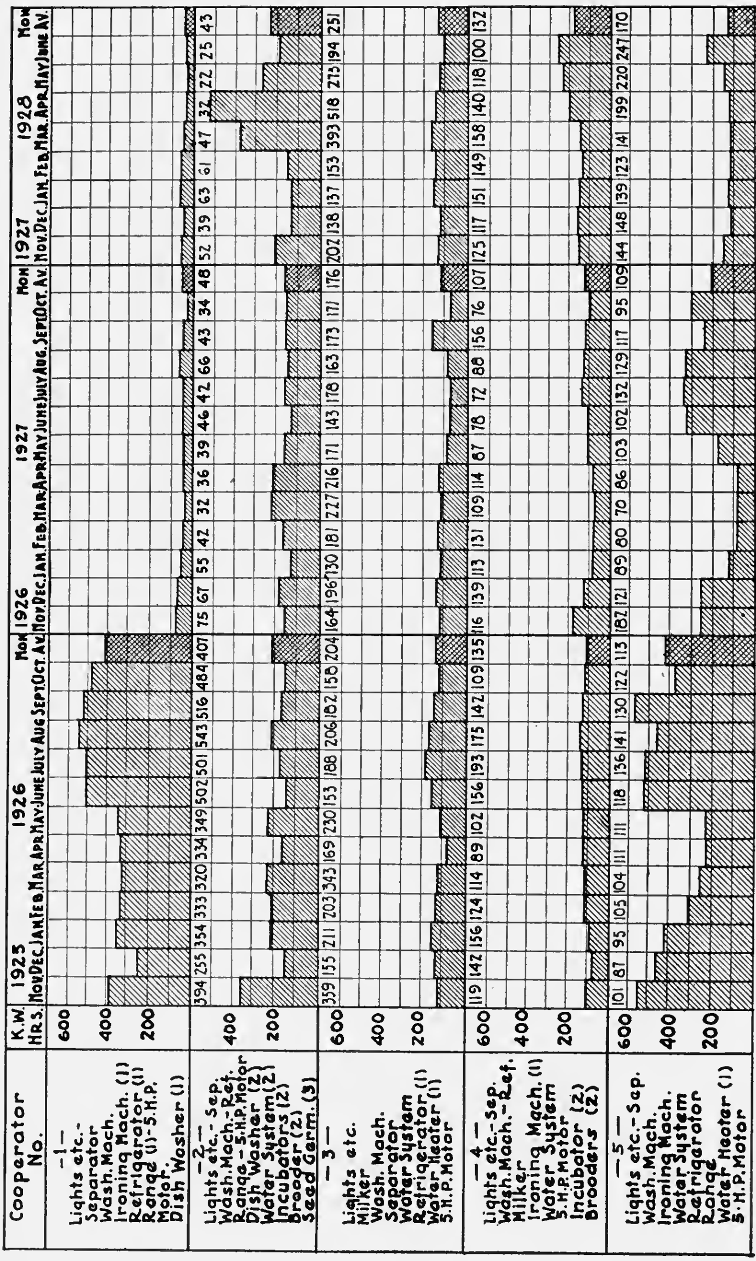


FIG. 5.—EQUIPMENT USED AND MONTHLY ENERGY CONSUMPTION ON FARMS OF COOPERATORS 1 TO 5

The normal use of electric service by the cooperators did not begin until November, 1926; prior to that time the energy, except what was used on the lighting circuit, was furnished without cost. The items of equipment marked (1) were removed at that time.

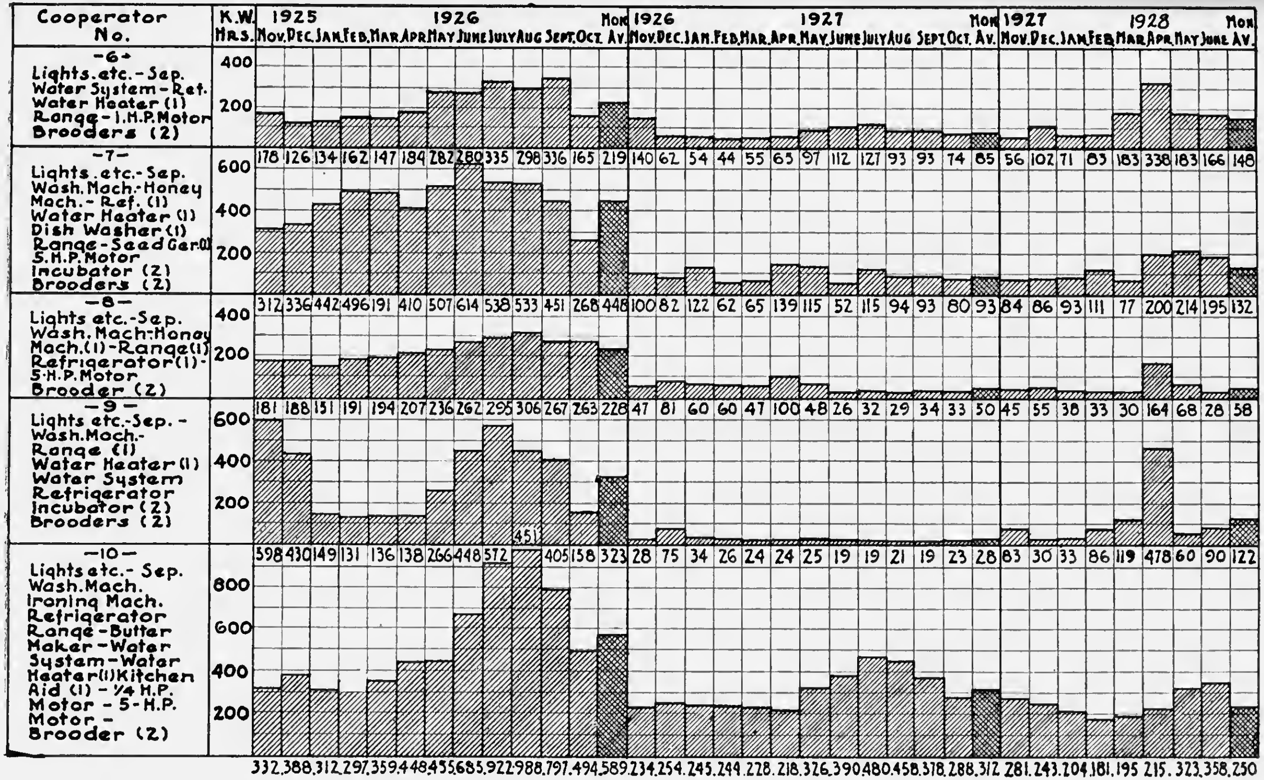


FIG. 6.—EQUIPMENT USED AND MONTHLY ENERGY CONSUMPTION ON FARMS OF COOPERATORS 6 TO 10

The increase in energy consumption in 1928 was due largely to the use of incubators and brooders (2) which were purchased in March of that year.

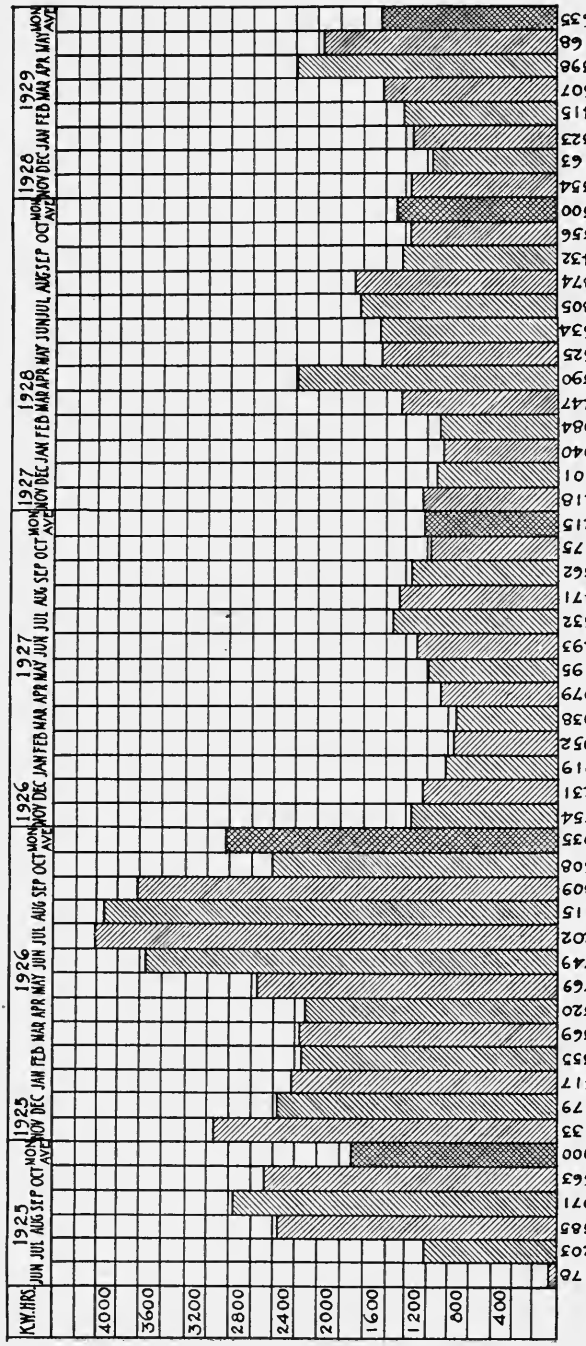


FIG. 7.—TOTAL MONTHLY ENERGY CONSUMPTION ON THE TEN COOPERATING FARMS

Contrary to general belief, more energy was used on these test farms during the spring and summer months than the rest of the year. This was due primarily to the greater use of ranges, refrigerators, and poultry equipment at that time.

It will be noted that the four smaller farms received 35 to 56 percent of their income from livestock, while the four larger farms received 6 to 11 percent of their income from livestock.

Kinds and Amounts for Different Types of Work

The energy used for all operations on the cooperating farms was derived from horses, gasoline, steam power, windmills, and electricity (Table 7). All the farms used horses, 7 used steam power and windmills, and 4 used gasoline engines, tractors, or trucks. Horses and tractors were complementary sources of energy for the drawbar work.

TABLE 7.—ENERGY SUPPLIED FROM VARIOUS SOURCES FOR DRAWBAR AND BELT WORK ON EIGHT COOPERATING FARMS, 1925-26

Source of energy	Average time used per farm	Conversion unit	Total converted units	Percentage of total units
	hrs.		*hp. hrs.*	*perct.*
Horse	8 799	1	8 799	67.3
Motor truck (8 hp.)	90.5	8	724	5.5
Tractor, drawbar[1]	184.5	6.53	1 204	9.2
Tractor, belt (30 hp.)	17.3	30	519	4.0
Gas engine (10 hp.)	3.4	10	34	.3
Steam engine (25 hp.)	19.8	25	495	3.8
Windmill (1 hp.)	359	1	359	2.7
Electricity	701.4[2]	1.34	940	7.2
Total	....	.....	13 074	100.0

[1]Conversion unit used for drawbar work was determined on the basis of accomplishment. [2]Electricity expressed in kilowatt hours.

On these farms, as on all farms, two types of power were needed —that for drawbar and that for belt work. The drawbar work made up by far the larger energy requirement, averaging 82 percent of the total energy used (Table 8).

TABLE 8.—ENERGY USED IN DRAWBAR AND BELT WORK ON EIGHT COOPERATING FARMS AND ON A GRAIN AND LIVESTOCK FARM, 1925–26

Type of power	Horsepower hours[1]			Percentage of total		
	Average of 8 farms	Grain farm 280 acres	Livestock farm 203 acres	Average of 8 farms	Grain farm 280 acres	Livestock farm 203 acres
Drawbar	10 729	8 530	7 845	82	85	77
Belt	2 343	1 562	2 285	18	15	23
Total	13 072	10 092	10 130	100	100	100

[1]The various units of power consumed in both types of work were converted into horsepower hours in order to obtain comparable totals for them.

TABLE 9.—PRESENT, UNDEVELOPED, AND POTENTIAL USES FOR ELECTRICAL ENERGY ON FARM OF COOPERATOR 4 DEVOTED TO GRAIN AND DAIRYING

	Description of use	Energy required		
		Per unit	Per year	Average per month
		kw. hrs.	*kw. hrs.*	*kw. hrs.*
Present uses				
Lights and household equipment	Lights for all farm buildings and minor household equipment	......	471	39
Refrigerator	Household use only	......	300	25
Milking machine	10 cows	......	361	30
5 horsepower portable motor	Grinding feed, elevating grain, and miscellaneous work	......	174	15
Total	......	......	1 306	109
Undeveloped load[1]				
Range	All cooking, 7 months and part 5 months (5 in family)	125 summer, 75 winter	1 250	104
Incubator	400 eggs a year	13.4 per 100 eggs	54	4
Brooder	300 chicks a year	2 per chick	600	50
Seed germinator[2]	Seed corn for 84 acres	2.15 per bu.	43	4
Deep-well pump	Water for stock and household	2.85 per 1,000 gals.	399	33
Ensilage cutter	75 tons a year	1.72 per ton	129	11
Straw baler	10 tons a year	3.5 per ton	35	3
Thresher	566 bushels of oats	.111 per bu.	322	27
	291 bushels of wheat	.265 per bu.		
	690 bushels of soybeans	.265 per bu.		
Total	......	......	2 832	236

[1]For operations now performed but not with electric power. [2]Commercial.

TABLE 9.—(*Concluded*)

	Description of use	Energy required		
		Per unit	Per year	Average per month
		kw. hrs.	*kw. hrs.*	*kw. hrs.*
Potential load[3]				
Radio battery charger	For radio during year	10 per month winter, 4 in summer	84	7
Milk cooler	280 pounds of milk a day	75 for 7 summer mos.	525	44
Poultry water heaters	150 hens, 4 winter months	5 per 100 hens	30	2
Lights for poultry	150 hens, 4 winter months	9 per 100 hens	54	4
Total	....	....	693	57
Grand total	....	....	4 831	402

[3]For uses that might be developed.

TABLE 10.—PRESENT, UNDEVELOPED, AND POTENTIAL USES FOR ELECTRICAL ENERGY ON FARM OF COOPERATOR 5 DEVOTED TO GRAIN PRODUCTION

	Description of use	Energy required		
		Per unit	Per year	Per month
		kw. hrs.	*kw. hrs.*	*kw. hrs.*
Present uses				
Lights and household equipment	Lights for all farm buildings and minor household equipment	...	412	34
Range	For most of cooking, family of 8	...	1 845	154
5-horsepower portable motor	Grinding feed and elevating grain	...	39	3
Deep-well pump	Household and stock	...	210	18
Total	...	...	2 506	209
Undeveloped load[1]				
Incubator	400 eggs a year	13.4 per 100 eggs	54	4
Brooder	300 chicks a year	2 per chick	600	50
Seed germinator	Seed for 170 acres	2.15 per bu.	90	8
Corn sheller	6,000 bushels	.02 per bu.	120	10
Thresher	1,967 bushels of oats 960 bushels of wheat 800 bushels of soybeans	.111 per bu. .265 per bu. .265 per bu.	684	57
Refrigerator	For household use only	40 per month	480	40
Total	...	...	2 028	169
Potential load[2]				
Radio battery charger	For radio during year	10 per month, winter, 4 in summer	84	7
Poultry water heaters	150 hens during 4 winter months	5 per 100 hens	30	3
Lights for poultry	150 hens during 4 winter months	9 per 100 hens	54	4
Total	...	...	168	14
Grand total	...	...	4 702	392

[1]For operations now performed but not with electric power. While there is a silo on this farm, it is not filled every year and the power for the operation of an ensilage cutter has not been included. [2]For uses that might be developed.

Steam power, windmills, and electricity were used for the belt work, which represented only 18 percent of the total work done on the farm. In its present stage of application, electricity may be seriously considered only for stationary or belt work in addition to its lighting and heating uses, which are not considered under this heading.

There is more belt work to be done on a livestock or dairy farm than on a grain farm. On a representative livestock farm belt work made up 23 percent of the total power demand, as compared to 15

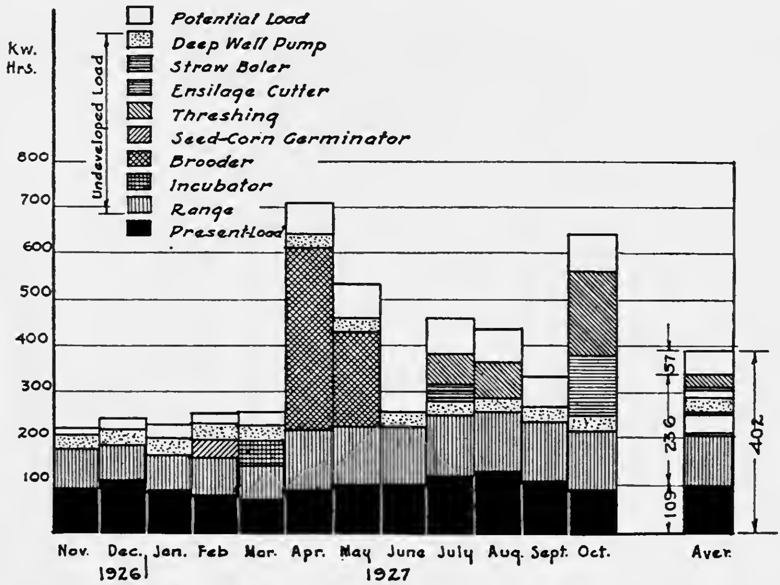


FIG. 8.—PRESENT, UNDEVELOPED, AND POTENTIAL ENERGY CONSUMPTION ON A 203-ACRE DAIRY FARM

This farm, owned by Cooperator 4, is typical of the grain and dairy farms in this section. Several items of equipment listed under "undeveloped," including a range, incubator, and brooder, were purchased and put into use in 1928.

percent on a representative grain farm. However, on the eight farms studied, the belt-power requirements on the four large farms were considerably higher than those of the livestock farms of smaller acreage. This was due to the total power requirements on these farms being greater.

Studies were made to learn what operations required belt power and how many horsepower hours of energy were used for each operation (Table 5). The largest amounts of energy were used for refrigeration, threshing, pumping water, grinding feed, and shelling corn.

Other belt operations, such as milking, washing, and cream separating, while consuming small amounts of energy, require it regularly thruout the year; hence a convenient source of energy is of particular advantage for them.

Just because electricity is a very convenient source of power on livestock, dairy, and poultry farms, where a large share of the labor of the farm is absorbed about the farmstead, it is not to be expected

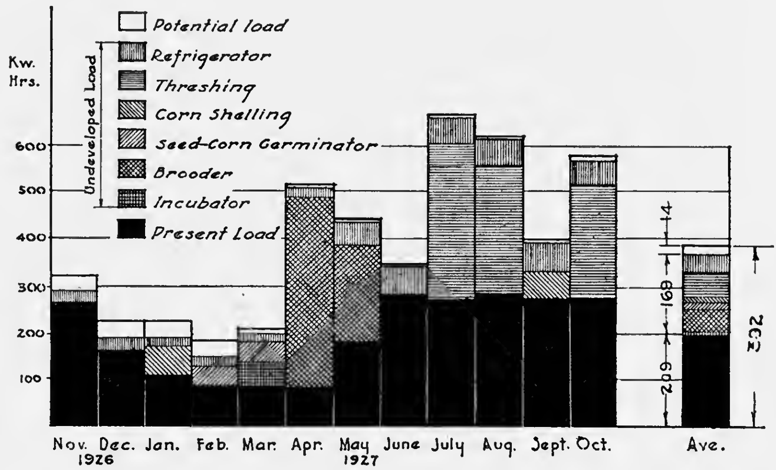


FIG. 9.—ESTIMATED POSSIBLE ENERGY CONSUMPTION ON A 320-ACRE GRAIN FARM

This farm, owned by Cooperator 5, was typical of the grain farms of the area. Eighty-nine percent of the income was from grain. The total possible use of electric power is not quite so great as on the smaller dairy farm.

that every farmer who gets electric service should change to those types of farming. On the contrary, it is essential that where electricity is available its use be adapted to the system of farming practiced in the section, and to the needs of the particular farm.

Potential Electrical Load for Two Representative Farms

As stated previously, the unit cost of supplying the farm with electricity depends upon the amount of use that is made of it. In Tables 9 and 10 and Figs. 8 and 9 an attempt is therefore made to show what maximum use could be made of electric energy on the farm of Cooperator 4, a representative dairy farm in the grain-producing area of Illinois, and on the farm of Cooperator 5, a representative grain farm, if used for all the operations for which it has proved practical.

The power requirements are divided into three groups; *first,* the load for which electricity was being used and for which the farmer was paying; *second,* the undeveloped load, or the amount of energy that would be required for those operations that were being performed by some other source of energy; and *third,* the potential load, or the requirement for those operations and practices not performed on the farm but which might profitably be performed and for which electricity has proved practical. A record of all the operations performed over a period of one year was used as the basis for calculating the total amount of electricity that would be required for the different uses described. The energy requirements for the different operations were calculated by using data obtained at this and other experiment stations.

Besides showing that both types of farms were using considerable electric power, these charts indicate, contrary to the usual belief, that there is practically as large a potential use for electricity on Illinois grain farms as on dairy farms. The load per mile of line, however, would be larger in a dairy area in Illinois than in a grain area because the average dairy farm is smaller than the average grain farm and there would be more of them to a given area.

Power and Labor Saved on Test Farms

To adopt electricity successfully as a source of power for farm operations, either the labor used should be made more productive or the new power must cost less than the power formerly used. The fact that labor and power make up from 50 to 70 percent of the total operating cost involved in crop production suggests the importance of any plan for their more effective use.

Thru the cooperation of the Department of Farm Organization and Management detailed labor and financial records were kept on eight of the ten cooperating farms from the beginning to the end of the study. These records were compared with those of another group of six farms which did not have service from a central power station. These six farms were chosen because they were the only farms in the area on which records similar to those on the cooperating farms were kept during the entire three years.

It is interesting to note that approximately 50 percent of the farm labor (Table 11) was performed on or about the farmstead in caring for livestock, repairing machinery, improving buildings, and grinding and hauling feeds for stock. A much smaller share of the total labor on a farm is used in the field in the production of crops and in hauling them to market than is often supposed. With farms having more livestock to the acre, the percentage of labor spent around the farmstead would be even larger.

While the records of the eight cooperating farms indicate a decrease each year in the proportion of time spent in performing tasks

about the farmstead, the larger part of the reduction seems to have been due to such general conditions as failure to make any major repairs on buildings during this period, for a similar decrease occurred on the six farms not having central power service. It seems probable, however, that part of the decrease between the first and second years resulted from the use of electricity in farm operations the second year. In the case of certain individual operations it is clear that electricity would materially lessen the man labor required. This is particularly true of the milking operation, and also of feed grinding when an electric motor replaces a tractor.

TABLE 11.—PERCENTAGE OF TOTAL FARM LABOR THAT WAS PERFORMED ON OR ABOUT THE FARMSTEAD ON EIGHT COOPERATING FARMS AND AVERAGE FOR SIX OTHER FARMS

Cooperator	1925	1926	1927
	perct.	*perct.*	*perct.*
1	51	47	49
2	52	50	53
3	61	53	51
4	66	60	60
5	53	51	49
7	53	45	46
8	58	56	45
10	52	43	36
Average of 8 cooperating farms	56	50	48
Average of 6 other farms	49	47	45

While electricity thus tended to reduce the labor required about the farmstead, in some instances it caused an increase by adding to the number of activities undertaken. Seed-corn germinators were operated where formerly this type of testing was not done on the farm. Poultry production was increased, and feed was ground where formerly it was bought.

Because of these two counteracting influences, the effect of the use of electricity is not fully indicated by the changes in the percentage figures. The fact that 50 percent of the labor of the farm is spent about the farmstead is perhaps of more significance, for it suggests the possibility of using electricity for light and power to make the labor of the farm worker more effective.

The actual application of electric power is discussed under the various uses which were studied.

SCOPE OF EQUIPMENT STUDIES

All facts concerning energy consumption by equipment, with the exception of a few tests made in the University laboratories and on the University farm, were obtained under actual farm operating

conditions on the ten cooperating farms. A number of pieces of equipment were installed on each farm and the use, value, and energy requirement of each piece determined in comparison with other equipment. Under this plan it was possible to build up a reasonably large load on each farm, resulting in a lower charge per unit of energy used.

Thru the cooperation of manufacturers, the following electrically operated equipment was used on the ten farms served by the test line:

10 refrigerators	6 ironers
10 vacuum cleaners	6 water heaters
10 cream separators	2 milkers
9 portable utility 5-hp. motors	2 dishwashers
9 washers	1 kitchen aid mixer
8 grain elevators	1 paint spray machine
8 ranges	1 buttermaker
8 feed grinders	1 15-hp. motor and substation
7 water systems	Other miscellaneous equipment

The distribution of this equipment by farms is shown in Figs. 5 and 6.

Tests were made also of poultry house lighting, seed germinating, silo filling, and other miscellaneous uses.

In many cases changing to electricity for the performance of various operations did not require much additional expense for equipment. To several washing machines and cream separators already in use, small electric motors were attached. The equipment cost of electrically operated water systems, incubators, brooders, and the seed-corn germinator were no more than the cost of similar equipment operated by other sources of energy. An electric range costs little, if any, more than a good coal range.

In the following pages, in two groups, are given the results of these equipment studies. The first group covers household uses of electricity and the second the uses of electricity in farm production.

In addition to securing data on the energy requirements of individual operations, a primary object in testing out various uses of electricity under practical conditions on a group of farms was to determine as accurately as possible the total practical use that could be made of electricity during each month of the year. The results obtained were largely due to the interest and cooperation of the individual farmers on the line.

HOUSEHOLD USES OF ELECTRICITY

Improved living conditions on the farm are generally recognized as one of the essentials of modern agricultural advancement. In making better living possible, electricity is playing an important part. The problem of modernizing the farm home and reducing the irksome-

ness of many chores becomes much easier of solution with electric power available.

Two groups of equipment are considered in this study of the adaptability of electric power to the farm home. In the first group is the larger equipment—the water supply system, including plumbing and sewage disposal, and the lighting equipment.[1] In the second

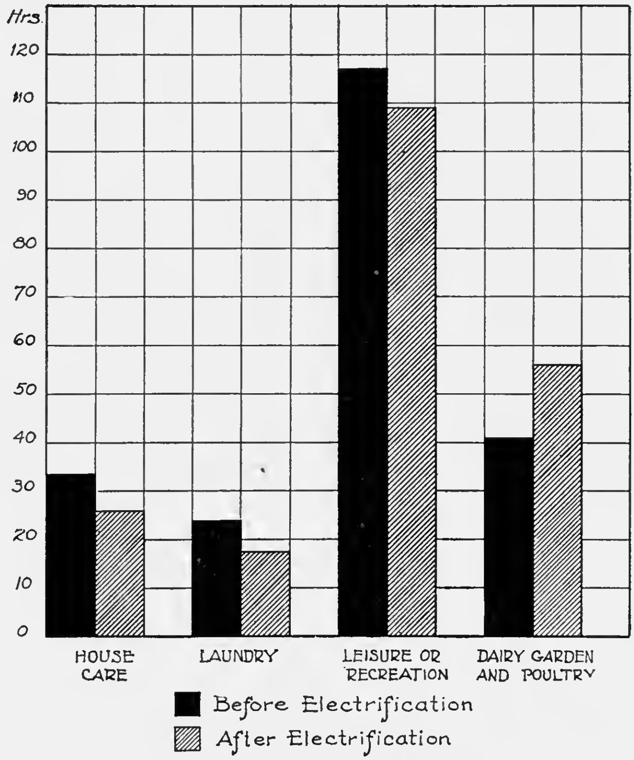


FIG. 10.—A COMPARISON OF TOTAL TIME SPENT BY FIVE HOME-MAKERS ON SPECIFIC ACTIVITIES BEFORE AND AFTER ELECTRIFICATION

The time saved in doing the work of the household with electrical equipment was devoted to productive work in the dairy and garden.

group are the movable labor-saving devices and conveniences such as washing machines, ironers, vacuum cleaners, ranges, food mixers, refrigerators, and other appliances of this kind. The principal part of this study on household uses of electricity was directed to the equipment in this second group.

[1]Altho electricity has been tried out for house heating, it has not proved satisfactory for this purpose under Illinois conditions, and was not included in this study.

Effect of Electrification on Housewife's Time

The first step in studying the use of electrical equipment in the farm home was to determine just how the women on these test farms used their time and the effect which the installation of electrical equipment had upon their expenditure of time. A week's record of the time devoted to household tasks, to recreation, and to sleeping by the women on five of the test farms was therefore taken before electrification and another week's record a year later. A summary of the data collected is given in Table 12.

While no definite conclusions can be drawn from results covering so brief a period and kept by so few women, certain tendencies may be noted. These are shown in graphical form in Fig. 10.

The vacuum cleaner saved from 1 to 5 hours weekly in caring for the house. Better laundry equipment saved from 1 to 4 hours a week. There was a tendency for less time to be spent in recreation, but this may have been due to the fact that the women were not so tired and therefore did not feel the need of so much rest as formerly.

More time was spent on the personal toilet after electrification than before. This difference may have been due to the investigational work, which brought increased personal contact, but as few visits as possible were made by the investigators during the time this information was collected.

Less time was spent in sleeping. This may have been due to the fact that better lights made it possible to read and do other things in the evenings that require a good light. It is possible that the women were less fatigued and so did not feel the need of the additional sleep.

The time spent on dairying and in the garden was 1 to 10 hours more a week after electrification than before. This would indicate that a large part of the time saved by using electrical appliances in the home was used in income-producing work.

Pumping Water for Household Use

A water system in the farm home not only is a convenience for the housewife but renders service to every member of the family. It ranks high among the items of equipment essential to a modern home. The first cost, however, rather than the operating cost has been found in tests to be the deciding factor when the farmer considers the purchase of a water system.

Data on energy consumption for the pumping of water for household use were obtained at four homes where water was being pumped from shallow wells by automatically operated, hydropneumatic systems. Water meters and electrical kilowatt-hour meters were installed

TABLE 12.—TIME SPENT BY WOMEN ON FIVE COOPERATING FARMS IN VARIOUS HOUSEHOLD TASKS BEFORE (1925) AND AFTER (1926) ELECTRICAL EQUIPMENT WAS INSTALLED

(Figures indicate hours and minutes per week devoted to specific tasks. Miscellaneous uses of time were not considered.)

Daily task	Cooperator 2		Cooperator 5[1]		Cooperator 6[2]		Cooperator 7[3]		Cooperator 8	
	1925	1926	1925	1926	1925	1926	1925	1926	1925	1926
Meals	31:15	28:50	35:45	27:25	26:25	29:00	34:35	42:10	24:15	38:05
Food preservation	.....	.....	.....	.....	.....	.....	8:10	3:45	.....	.....
Marketing	2:00	1:50	1:15	5:05	5:50	4:45	4:35	5:45	5:40	5:45
Sewing	1:00	:55	12:30	7:30	:50	9:00	3:45	:15	4:40	1:35
House care	8:15	6:30	16:30	15:05	9:15	4:05	1:30	2:15	6:25	4:25
Laundry	4:40	3:35	6:45	8:55	2:20	.....	4:30	3:00	7:45	2:05
Children	.....	.....	.....	.....	.....	.....	:20	:00	2:00	1:05
Personal toilet	4:15	7:20	:55	4:50	4:25	2:30	2:10	3:30	2:20	4:20
Recreation	45:05	34:15	13:20	27:25	20:30	18:15	32:05	41:15	35:25	15:05
Dairy	1:20	3:15	1:00	1:10	2:05	:45	5:50	9:20	1:30	7:15
Farm work	.....	.....	.....	.....	:25	.....	.....	.....	3:45	.....
Garden	.....	2:40	1:40	3:30	1:05	2:00	:50	2:50	2:30	7:55
Poultry	5:00	8:20	1:35	:20	13:55	8:10	9:10	8:20	4:25	4:15
Helping neighbor	.....	.....	:30	.....	.....	.....	.....	.....	.....	.....
Sleeping	56:10	55:15	65:45	60:10	53:35	51:45	64:15	55:50	54:30	55:55
Nursing	.....	.....	.....	.....	.....	.....	2:05	.....	.....	.....
Receiving callers	.....	.....	7:15	3:30	1:40	1:45	.....	.....	.....	.....
School work	.....	.....	.....	5:55	.....	.....	.....	.....	.....	.....

[1]Records were kept for 1925 and 1926 by different individuals. [2]Based on six days. [3]Based on eight days.

TABLE 13.—ELECTRIC ENERGY CONSUMED IN PUMPING WATER FROM SHALLOW WELLS ON FOUR COOPERATING FARMS, 1925-27[1]

Cooperator	Type of pump	Number in family	Rating of motor	Capacity of pump	Pressure	Year	Amount of water used: Monthly total	Amount of water used: Daily per person	Average energy used per month	Energy used per 1,000 gals.
			hp.	gals. per hr.	lbs.		gals.	gals.	kw. hrs.	kw. hrs.
3	Double-acting	8	¼	...	10–35	1925–26	1 061.5	4.42	2.04	1.92
						1926–27	1 188.7	4.94	2.41	2.03
9[2]	Single-acting	2	¼	180	15–35	1925–26	354.0	5.90	1.22	3.45
						1926–27	327.7	5.46	.83	2.54
9[3]	Double-acting	4	¼	200	12–32	1925–26	3 800.0	31.63	4.37	1.15
						1926–27	3 567.0	29.75	4.32	1.21
10	Double-acting	11	¼	200	10–30	1925–26	1 872.5	5.68	1.97	1.05
						1926–27	1 711.5	5.20	2.00	1.17
Average	Single-acting	2	¼	180	15–35	1925–27	340.8	5.60	1.02	3.00
Average	Double-acting	7.6	¼	200	10.6–32.3	1925–27	2 200.0	9.50	3.12	1.42

[1]All water systems were of the automatic-control hydropneumatic type. [2]Found air leak in pipe (1925-26). The other systems were double-acting pumps. [3]All cooperators except No. 9 used additional water from deep-well systems. No. 9 used a small amount of water for drinking purposes which is not included above.

and readings of all meters were recorded each month during the test, which lasted for two years. The results are shown in Table 13.

Three double-acting water pumps operated under farm conditions required an average of 1.42 kilowatt hours to 1,000 gallons of water pumped (Cooperators 3, 9, and 10). The greater energy consumption of the single-acting pump (Cooperator 6) during the first year was due largely to a slight air leak in the suction pipe. The average lift was about 10 feet. The range in pressure was from

TABLE 14.—WATER CONSUMPTION AT NINE FARM HOMES EQUIPPED WITH MODERN PLUMBING

Farms	Period during which measurements were taken	Number of people	Volume per person per day
			gals.
A.	6- 5-25 9- 4-25	3	47.5
B.	6-11-25 7-10-25	3	17.0
C.	5- 4-26 8- 3-26	4	21.1
D.	3- 1-26 3- 1-27	4	30.4
E.	6-15-25 12-21-25	7	15.0
F.	8- 1-25 6- 4-26	8	10.0
G[1]	6-19-25 6-19-26	5	38.0
H[1]	6-19-25 6-19-26	5	45.8
I[1]	6-19-25 4- 3-26	4	29.0

[1]Farms G, H, and I were supplied with University water pressure and the tenants were not charged for water used.

10 to 35 pounds. The monthly energy consumption for pumping water for household use ranged from .5 to 7.0 kilowatt hours, averaging 2.4. kilowatt hours for all pumps under test.

Considerable water was used in the cooperating farm homes from sources other than the water systems under test, and this made it impossible to secure a record of the total amount used in the home. The data from another study of nine farm homes equipped with such plumbing fixtures as kitchen sink, bathtub, lavatory, toilet, and laundry facilities (Table 14) show wide differences in the amounts

of water used per person per day. The lowest amount was 10 gallons and the highest 47.5 gallons. Part of this difference is to be accounted for by differences in equipment and part to habits of the individual families.

Laboratory tests were made on electrically driven, single-acting reciprocating, double-acting reciprocating, and rotary pumps under various pressures. The data secured indicate that the actual efficiency of such plants is low. However, the cost of operating them is slight, and they are so convenient that the question of efficiency is not to be given very much consideration when compared with other methods of pumping. From the study of such plants, however, it is evident that many could be operated with greater economy than at present. Fifteen to 25 percent more power is required when the range of working pressures is set for 20 to 50 pounds than when set for 10 to 20 pounds, which under practically all conditions is satisfactory.

The efficiency of the particular rotary pump tested was higher than the reciprocating pumps at low pressures but was practically zero at 50 pounds pressure. The laboratory tests showed two double-acting reciprocating pumps more efficient and one less efficient at low pressures than the single-acting reciprocating pump. The tests under farm conditions showed that the double-acting reciprocating pumps were more efficient.

Some of the advantages of an electrically driven water system and complete plumbing that were recognized by the users were the following:

1. Labor and time are saved by having water where it is needed.
2. Complete bathroom fixtures are possible.
3. A constant supply of water for livestock and poultry is assured.
4. The protection to farm buildings from fire is increased. The water pressure and the water supply may not be adequate for extinguishing a well-established fire, but if the fire is discovered in time, the pressure system certainly would have an advantage over the bucket method.
5. The health of the family is protected by the better disposal of sewage.

Water Heating

Tests were made to determine the efficiency of two types of heaters—the inexpensive open type connected to an ordinary hot-water tank, and the more expensive thermos-bottle type.

Five water heaters of the open, or exposed, type, with a capacity of 3,960 watts each, were connected to uninsulated hot-water tanks in five farm homes. No charge was made for the energy and the water was used more freely on some farms than others, but no record

of the amount or the temperature of the water was kept. The only value of the data is to show the monthly energy consumption. During the month of August on one farm where there was a family of eleven, one of these heaters used 475 kilowatt hours of energy. During the month of July, at another farm home, where there were eight persons in the family, a similar water heater used 171 kilowatt hours. This type of heater was very wasteful in the use of electricity.

A 15-gallon thermos-bottle type of water heater was used in one farm home. This heater was equipped with a 2-hour time switch, automatic temperature switch, and a 3000-watt element in the base of the tank which was well insulated. The energy consumed by this heater was 293.6 kilowatt hours per 1,000 gallons heated. The water was generally heated for two hours in the morning, reaching 150° Fahrenheit. It remained warm enough for most purposes thruout the day. On wash days, when considerably more water was used, the heater was turned on again at noon.

TABLE 15.—ESTIMATE OF AMOUNTS OF HOT WATER USED BY DIFFERENT-SIZED FAMILIES WITH AND WITHOUT WATER UNDER PRESSURE

No pressure system (based on 69 reports)		Pressure system (based on 39 reports)	
Number in family	Gallons per person daily	Number in family	Gallons per person daily
2	6.62	2	8.80
4	3.95	4	6.37
7 or over	2.5 to 3.10	7 or over	3.75 to 4.28
Average 4.1	4.28	4.46	5.92

Information on the amount of hot water used in farm homes was secured from a group of home advisers. This data is shown in Table 15. It is evident that the actual amount of hot water needed will depend somewhat on the habits of the individual family as well as on the convenience of the equipment. On the basis of the data in this table a family of four persons, with a pressure water system in use, would need 764.4 gallons of hot water during thirty days. From the results of experiments with the insulated thermos-bottle type of tank it is calculated that 225 kilowatt hours would be required to heat this amount of water sufficiently for household use.

Because of the convenience of a hot water supply, a low energy charge would make water heating by electricity practical in reasonably small quantities. While the number of heating units available per kilowatt hour limits the use of electricity for water heating, there are possibilities for practical use of electricity for heating water

in a well-insulated tank when the current is connected with a time switch so that the heater will be in operation after midnight, when the electrical load is very slight and the energy used may be purchased at a lower rate.

Tests of Washing Machines

In washing and ironing, as in many other household operations, the matter of equipment is only one of a number of important factors. The water supply, the method of heating the water, and the facilities for drying the clothes all affect the ease with which laundering is done.

Fig. 11.—Washing and Ironing Machines in Home of Cooperator 10

Electric power was applied to the double-tub washer by means of a motor attachment. By the use of these machines the time required to do the jobs of washing and ironing was cut about in half.

Only a limited number of tests were made to determine the effort expended in doing the household washing before electricity was available. Eight of the ten farms used gas engines, one used a hand-operated machine, and one washed without a machine. To wash 100 pounds of clothes without a machine required 11.2 hours; with a hand-operated machine 10 hours were used; and with the gas engine for power 7.5 hours were used. The distance walked when using hand methods was 10.2 miles; with the hand-operated machine, it was 7.1 miles; and with the machine operated by a gas engine, it was 6.4 miles, all per 100 pounds of clothes.

After electricity was available, records were kept on 6 washers of the oscillating type and 1 of the double-tub dolly type. Table 16 gives a summary of one year's washing records secured on the farms. To wash 100 pounds of clothes required an average of 1.52 kilowatt hours of electric energy and 8.7 hours of labor. The distance walked by the farm women was 4.47 miles to 100 pounds of clothes. A total of 275 weekly washings were included in the test and the number of pounds of clothes washed was 10,211, or an average of 37 pounds a week.

There was considerable difference in the time required, the distance walked, and the amount of electricity used by the different women. The operator completing the washing in the least time required only 5.9 hours of labor, walked 3.37 miles, and used 1.11 kilowatt hours of electricity to wash 100 pounds of clothes; the one taking the most time required 11.6 hours of labor, walked 5.12 miles, and used 2.22 kilowatt hours of electric energy. The factors having most influence on the efficiency of the operation were the type of washer and the location and arrangement of the equipment.

While detailed records such as the above were kept for only one year, a record of the energy consumed by the washing machines was continued thruout the experiment. In 1927 the amount of energy consumed monthly ranged from 1.25 kilowatt hours in a family of two to 3.16 kilowatt hours in a family of seven, averaging 2.37 kilowatt hours a month for the eight cooperators. The energy consumption per person per month varied from .23 kilowatt hour in a family of eleven to .62 kilowatt hour in a family of two, averaging .36 kilowatt hour for all eight families.

Some idea of the value of the time spent by these farm women in doing their washing can be determined by comparing their costs with what the service of a city laundry would have cost them. In one farm family where a total of 1,858 pounds of clothes (dry weight) were washed on 50 wash days over a period of a year, 28.1 kilowatt hours of energy were used and 136.4 hours of labor were required. Twenty gallons of hot water and 1¾ bars of soap were used each week to do the washing. The expenses were:

Cost of energy, 281 kw. hrs. at 10 cents	$ 2.81
87½ bars of soap at 6¼ cents	5.47
16⅔ gals. of kerosene for heating water, at 12 cents	2.00
15 percent on $175 for interest and depreciation on equipment	26.25
Depreciation and interest on investment in wash tubs, boilers, buckets, and washboard (assumed)	3.00
Bluing, starch, washing powder (assumed)	12.00
Total	$51.53

The charge by the city laundry for 1,858 pounds of washing returned rough dry, at 10 cents a pound, would be $185.80. Laundry

that is finished rough dry has the flat pieces ironed. The difference between the cost of doing the laundry at the farm and that at the city laundry, $134.27, may be considered the value of the 136.4 hours of labor used in doing the work at home. This is only a little less than $1.00 an hour. The saving in time required to take the laundry to town and have it returned would approximate the time required to iron the flat pieces.

If we assume the city laundry would call for and deliver a wet wash ready to be ironed at a cost of 5 cents a pound, then the comparison would show a saving of $41.38. In this case the housewife would earn only 31 cents an hour for her labor in doing the job of washing; however, there are relatively few farms located so they can get free delivery service.

Where a gas engine was used as a source of power for washing, a little less labor time was required than where an electric motor was used. This was probably due to three different factors; *first,* the types of washing machine used—most of the farm women, in changing from the dolly to the oscillator type of machine, thought the latter was slower; *second,* a man usually started the gas engine and saw that it ran properly, but his time was not counted; and *third,* there was greater haste, in order to get thru with the job before the engine stopped.

The electric motor for driving a washing machine is practical, economical, and entirely satisfactory. The energy used is very slight and the cost per week is a very small item. The cleanliness, ease of control, and the ever-ready power of an electric motor are characteristics which make it an important factor in the solution of this difficult household problem.

Tests of Electric Ironers

Farm Tests. Studies of electric ironers were made both in the homes of the cooperating farmers and in the laboratory. The value of the 26-inch ironer as a time saver, on the basis of actual farm tests, is suggested by the records summarized in Table 17. The number of hours of labor required to iron 100 pounds of clothes with the old-fashioned sad irons was 14.89; the number of hours required with an electric iron, 10.27, and with the 26-inch ironer, 7.58.

Three of the six ironing machines that were used experimentally the first year were purchased by three of the farmers. The average energy used each month by these ironers was practically the same as the average for all six the previous year.

The ironers proved of special value in homes where there were large families. In some instances, where most of the ironing consisted of flat pieces, the time saved over hand ironing was about one-half.

TABLE 16.—WASHING-MACHINE RECORDS KEPT BY SEVEN COOPERATORS, 1925-26

Cooperator	Number in family	Number of washings	Distance walked per washing	Labor time	Washer time	Total energy used	Dry weight of clothes	Number of batches	Dry weight per batch	Per 100 pounds clothes: Distance walked	Per 100 pounds clothes: Labor time	Per 100 pounds clothes: Washer time	Per 100 pounds clothes: Energy used
			miles	hrs.	hrs.	kw.hrs.	lbs.		lbs.	miles	hrs.	hrs.	kw.hrs.
1.	7	48	1.36	210.9	113.2	24.2	2 101	265	7.9	3.10	10.0	5.38	1.15
2[1].	2	26	1.52	45.1	27.0	12.5	583	90	6.4	6.77	7.7	7.72	2.14
3.	8	49	1.5	167.7	139.2	32.0	1 436	251	5.7	5.12	11.6	9.69	2.22
4.	5	50	2.22	136.4	108.9	28.1	1 858	288	6.4	5.97	7.3	5.86	1.51
7[1].	7	22	2.0	77.6	48.0	14.6	1 306	198	6.6	3.37	5.9	3.67	1.11
8.	4	32	. . . .	81.2	60.0	12.0	1 021	170	6.0	. . . .	7.9	5.88	1.17
10.	11	48	1.63	175.2	140.9	32.4	1 906	218	6.0	4.12	9.1	7.39	1.70
Average. . . .	. .	. .	. . . .	. . . . .	. . . . .	. . . .	. . . . .	. . .	6.9	4.47	8.7	6.24	1.52

[1]Nine months' record.

TABLE 17.—TIME AND ELECTRIC ENERGY REQUIRED IN IRONING WITH SAD IRON, ELECTRIC IRON, AND IRONING MACHINE

Kind of iron	Average number in family	Dry weight of clothes	Total time[1]	Average weight per ironing	Per 100 pounds clothes: Labor time	Per 100 pounds clothes: Energy used	Energy per month: Min.	Energy per month: Max.	Energy per month: Aver.	Energy per month: Per person
		lbs.	hrs.	lbs.	hrs.	kw.hrs.	kw.hrs.	kw.hrs.	kw.hrs.	kw.hrs.
Sad iron[2].	. . .	136.5	20.25	17.00	14.89	. . . . .	. . . .	. . .	. . . .	. . . .
Electric iron[3].	2	68.25	7.01	13.65	10.27	6.30	3.2	3.3	3.25	1.62
Ironing machine, 26-inch roll[4].	7	3 546.2	268.81	24.70	7.58	11.16	2.25	9.8	6.40	.91

[1]To sprinkle, iron, and fold. [2]Data from a few records kept by state cooperators. [3]Data from a few records taken on experimental line. [4]Records kept over period of year on six ironing machines.

Some objections were made to the short-roll machines because of the necessity of folding tablecloths and other wide pieces. However, the short-roll machine wastes less heat than the long-roll.

Some difficulty was experienced at first in operating the ironing machines, but the longer they were used the more proficient the women became. One machine broke a large number of buttons on the clothes owing to light padding on the roll.

The results of this study indicates that where a large quantity of clothes and household linen is ironed each week, sufficient time and labor are saved to justify the use of an ironing machine. While more electric energy is required to iron the same quantity of clothes with the ironing machine than with the electric hand iron, the value of the time and effort saved is in favor of the ironing machine.

Laboratory Tests. Thru the cooperation of the Home Economics Department, tests were made in the laboratory to determine the effect of moisture content upon the time required for ironing certain articles of clothing and to study the efficiency of different lengths of roll from the standpoint of time and electrical energy consumed.

A machine with a 32-inch roll, preheated 20 minutes, was used in the tests to determine the effect of amount of moisture on rate of ironing. Two centrifugal driers were used. One of these was part of a washing machine. It was noted that the special centrifugal drier having a high cylinder speed reduced the moisture content more in a given period of time than the drier which is an attachment of a washer.

The time required for ironing involves two factors—the time for manipulation and the time required to remove the water. The results of these tests indicate that in ironing flat pieces, where the time needed for manipulation is reduced to a minimum, the ironing time is proportional to the percentage of moisture present.

Three ironing machines of two different makes having different lengths of roll were used in making the efficiency tests. All three machines differed in the design of the open end, wattage per square inch of shoe surface, metal in shoe, speed of roll, and the control switch or lever that operated the roll. These variable factors made it impossible to make an exact determination of the effect of the length of the roll on its efficiency. The procedure was as follows: the clothes were dried to approximately the same moisture content by means of a centrifugal drier and were weighed just before being ironed and immediately after they were ironed. The dry weight of the clothes was determined by drying them in an oven. The machines were preheated to approximately the same temperature before the tests were made, and the same pieces of clothes were run thru each machine, making it necessary to operate one ironer at a time.

The number of grams of water driven off per watt hour by each machine for the different kinds of clothes ironed is shown in Fig.

12. The long-roll machine removed less water per watt hour than either of the two short-roll machines. This was due to the fact that the operator could not keep the long-roll machine full from

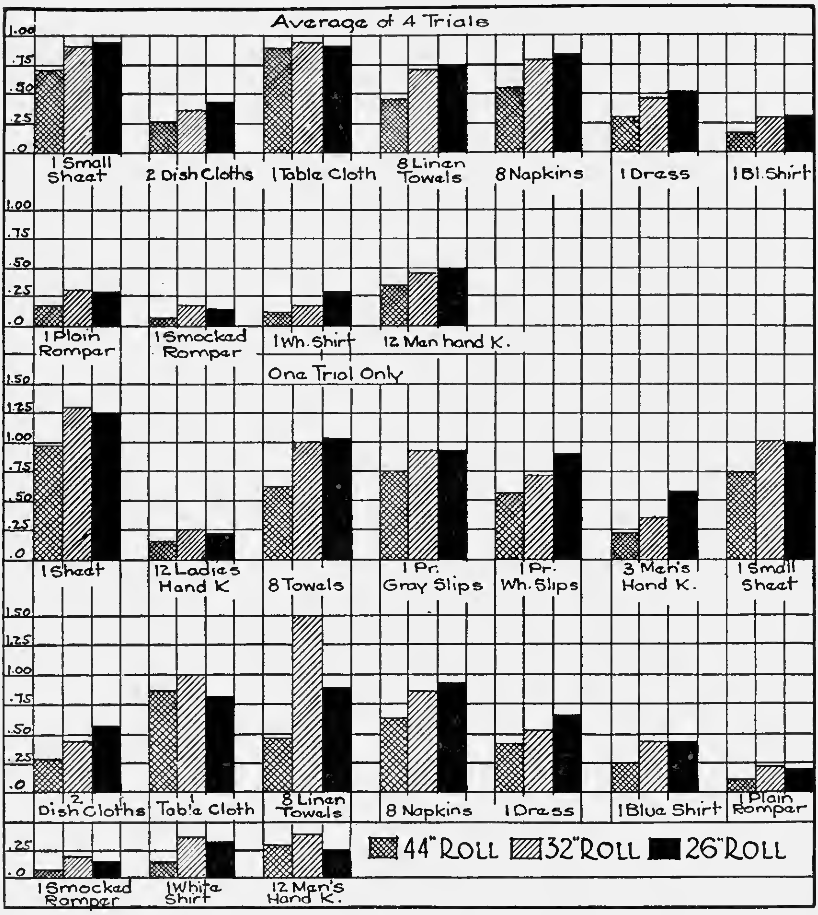


FIG. 12.—EFFICIENCY OF DIFFERENT LENGTHS OF IRONERS IN REMOVING WATER FROM ARTICLES OF CLOTHING

The bars indicate the number of grams of water removed for each watt hour of energy used. The results of the tests show that except for large, flat pieces, the short-roll machines are more efficient users of electricity than the long-roll machines.

end to end. The average of the four tests showed little difference between the long-roll machine and the short-roll machine in removing water where large flat pieces such as sheets and tablecloths were ironed. The machine with the shortest roll consumed less energy

per unit of work done than the other machines. As compared with ironing by hand, the long-roll machine saved about 35 percent more time than the short-roll machine on large flat pieces, but it did not save any time over the short-roll machine where small or difficult pieces were ironed.

Further tests, where all the mechanical features of the machines are kept as nearly constant as possible, should be made before definite conclusions are drawn relative to the effect of the length of the roll on energy consumption and rate of ironing. From results obtained, however, it is evident that for the average operator the short-roll machine is more efficient than the long-roll machine in conserving energy. The quality of work done was about the same except in the case of the large flat pieces, with which the long roll did the better job.

Cooking by Electricity

Farm Tests. One year's record of the energy consumed in the operation of electric ranges in farm homes is given in Table 18.

In a few of these homes coal ranges were used part of the time during the winter months, and in all of them ranges were given limited use for heating water for such purposes as dish washing. From May to September the electric ranges were used to do all the cooking.

The most striking difference in the energy consumption during the summer months will be noticed in the record of Cooperator 2. During June, July, and August this cooperator did not heat any water on her electric range. The results show that over 50 percent of the energy used previously was used to heat water. Cooperator 8 did not heat much water on her electric range, which also shows a low energy consumption for a family of four. Considerable fruit canning was done in the summer on practically all the electric ranges.

The average energy consumption per person per month for eight cooperators using electric ranges during the year 1925-26 was 32.5 kilowatt hours. The energy consumption per person per month ranged from 23.7 kilowatt hours in a family of 11 to 66.8 kilowatt hours in a family of 2, and the average monthly energy consumption ranged from 117 kilowatt hours in a family of 2 to 319 kilowatt hours in a family having an average of 7.5 persons.

The maximum average energy consumption occurred during September and the minimum during March. The average amount of energy used monthly by each range during the different seasons was: summer months, 215 kilowatt hours; fall months, 212 kilowatt hours; spring months, 168 kilowatt hours; and winter months, 168 kilowatt hours. It is interesting to note that monthly energy consumption was practically the same during the summer and fall months and the same during the winter and spring months.

TABLE 18.—ENERGY CONSUMPTION OF ELECTRIC RANGES IN HOMES OF EIGHT COOPERATORS, 1925-26

Cooperator	Number in family	Rating of range	Kilowatt hours used each month												Energy used	
			Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Yearly	Per person monthly
		kws.													*kw.hrs.*	*kw.hrs.*
1	7½	8.0	272	191	278	256	251	254	276	405	388	417	419	418	3 825	42.5
2	2	6.8	309	132	163	172	201	124	152	55	62	82	86	65	1 603	66.8
5	8	7.0	342	248	320	212	166	134	211	212	206	185	334	233	2 803	29.2
6	2	7.0	97	61	71	93	76	123	137	180	138	180	175	82	1 413	58.8
7	8	8.0	223	190	170	179	227	188	217	184	227	254	227	161	2 447	25.4
8	4	7.0	93	105	76	131	110	122	123	139	142	145	142	161	1 489	31.0
9	4½	6.8	98	92	76	71	59	55	139	158	246	243	320	84	1 641	30.4
10	11	7.0	229	272	192	289	126	301	270	287	286	343	295	238	3 128	23.7
Average	5.9	7.2	208	161	168	175	152	163	191	203	212	231	250	180	2 294	32.5

TABLE 19.—ENERGY CONSUMPTION OF ELECTRIC RANGES IN HOMES OF FOUR COOPERATORS, 1926-27

Cooperator	Number in family	Rating of range	Kilowatt hours used each month												Energy used	
			Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Yearly	Per person monthly
		kws.													*kw.hrs.*	*kw.hrs.*
2	2	6.8	78	88	32	47	76	58	62	67	83	76	78	92	837	34.87
5	7	7.0	151	106	63	48	40	47	133	240	233	245	207	247	1 760	20.95
6	2	7.0	32	31	29	22	33	42	75	92	108	70	69	48	651	27.12
10	11	7.0	138	97	102	102	110	103	187	251	287	304	203	170	2 054	15.56
Average	5.5	6.95	100	81	56	55	65	62	114	162	178	174	139	139	1 325	20.08

The energy consumption of the range owned by Cooperator 2 continued to be low in 1926-27 (Table 19); the average energy consumption per person per month for all four cooperators during this year was only 20 kilowatt hours as compared with 32.5 kilowatt hours the previous year. A coal range was used part of the time by each of these four cooperators during late fall, winter, and early spring.

The use of a pressure cooker to prepare an entire meal at one time was an important factor in reducing the energy consumption of the electric ranges. Records kept on cooking such combinations as mashed potatoes, cabbage, and chile con carne; or custard, scalloped

FIG. 13.—ELECTRIC RANGE IN HOME OF COOPERATOR 5

The average energy consumption per person per month for four cooperators was 32.5 kilowatt hours in 1925-26 and 20 kilowatt hours in 1926-27. Pressure cookers were an important factor in reducing the energy consumption of these ranges.

potatoes, baked beans, and Swiss steak, show that from 50 to 60 percent of the energy is saved over the ordinary method of cooking on the grids. Two of the cooperators had economy cookers, which saved energy as well as time.

Energy is saved also by an orderly and well-planned menu, cooking breakfast foods in the oven on the evening's stored heat, and by turning the switch to either medium or low in cooking when the water has started to boil. The placing of pans of water in the oven, or on top of the hot grids after the meal has been cooked aids in solving the hot water problem for washing dishes.

The cost of cooking meals on an electric range as compared with other methods is somewhat higher, but such advantages as tempera-

ture control, automatic control, cleanliness, etc., will make the difference in cost seem worth while to many. It should be remembered that electricity was furnished free during the first year's tests and that the cooperators lacked experience in operating electric ranges. This no doubt accounts partly for the difference between the amounts of energy used during the two years.

Laboratory Tests. A test to determine the most economical method of cooking certain meals on the electric range, from the standpoint of energy consumption, was made in the Home Economics laboratory of the University of Illinois.

Some preliminary studies were made in farm homes to determine typical farm menus and to try out different combinations. Two menus were chosen as being representative. The selection was guided by cooking records kept by the farm women cooperating on this project, and the amounts of food prepared were determined on the advice of a nutrition specialist. The first menu selected was beef, potatoes, corn, cabbage, and custard. This menu was chosen as one which lent itself well to several methods of cooking. The second menu selected was pork, navy beans, potatoes, tomatoes, apple pie, and biscuits. This was chosen because it did not lend itself well to different methods of cooking. When the meal is cooked in the oven, the biscuits must be baked at the end of the cooking period and require a very high temperature, which makes it impossible to do much of the cooking on stored heat; and when the meal is cooked on top of the stove, it is necessary to heat the oven in addition in order to bake the pie and biscuits.

The quantities of food chosen were based on the needs of a farm family of six and were as follows:

Menu No. 1

3 pounds of beef
1 No. 2 can of corn
2½ pounds of potatoes (after paring)
1½ pounds of cabbage
1 quart of milk for custard

Menu No. 2

3 pounds of pork
1 No. 2 can of tomatoes
2½ pounds of potatoes (after paring)
2½ pounds of apples for pie (unpared)
3 cups of flour for biscuits
1 pound of dry navy beans

Three series of tests were made. In one the meals were cooked in the oven; in another, the meals were cooked on the platform heaters; in a third, the meals were cooked in a pressure cooker. Two different ranges were used and as nearly as possible the same utensils were used on both ranges. The beef dinners consistently required

less energy to cook than the pork dinners. This raises the question as to what food combinations prove the most economical when the cost of cooking is considered.

With one range there was more energy consumed when the pork dinner was cooked on the surface heaters than when it was cooked in the oven. When the beans were parboiled in the oven, the amount of energy used was less than when the whole dinner was cooked on the oven top. With the other range less energy was used when the pork dinner was cooked on the surface heaters than when cooked in the oven. This was true also of the beef dinners on both ranges.

The amount of energy required to cook the beef dinner with the pressure cooker was only slightly less than with platform heaters, but it was considerably less than with the oven. The pressure cooker did not seem to affect greatly the amount of energy used to cook the pork dinner.

Food Mixing

Records were kept to determine the energy used in mixing food in a machine known as the kitchen aid. This piece of equipment is operated by a $\frac{1}{10}$-horsepower motor and has the following attachments: wire loop whip, beater, pastry knife, bread hook, mixing bowl, food chopper set, special triple action three-quart ice cream freezer, oil dropper for mayonnaise, ice or hot water jacket, pouring chute, slicer and ice chipper, colander and sieve set, and roller for colander and sieve.

The energy consumed by the kitchen aid was very slight. In a family of 11 only 1.2 kilowatt hours per month were used, and in a family of 8 only about .5 kilowatt hour. The machine was found to be very helpful during canning season. Cooked fruits to be made into butters or jams could be put thru the colander when hot, thus saving time. During threshing, corn husking, and silo filling seasons it was very useful for such operations as slicing or mashing potatoes, mixing or beating eggs, whipping cream, grinding meats, etc.

Making Coffee With Percolator

A test was made by the Home Economics department to determine the amount of electricity used in making coffee with the electric percolator and the ordinary percolator when heated on an electric range.

Six cups of coffee were made in an electric percolator using 57 grams (about 8 level tablespoonfuls) of coffee and heating it to the boiling point. One hundred sixty-five watt hours of current were used. The same amount of coffee was made in an ordinary aluminum percolator set on the large platform heater of an electric range. The switch was turned to low position so that only the heating coil in the center was hot. The energy consumption with the ordinary percolator was 415 watt hours.

The ordinary percolator used was not the most efficient type and the data, therefore, cannot be considered conclusive, but they indicate that it may be economy to use an individual electric unit for some purposes rather than to cook on the platform heaters on the range.

Electric Refrigeration

Some means of keeping food cool in order to keep it palatable and prevent waste is an important consideration in every home.

An electric refrigerator was installed in the home of each of the ten cooperating farmers in order to study its use and determine its energy consumption and the effect of different conditions on energy

FIG. 14.—ELECTRIC REFRIGERATOR IN DINING ROOM OF COOPERATOR 4

From April to September inclusive the 10 refrigerators on test required an average of 56.1 kilowatt hours a month. The dining room is not an ideal location for an electric refrigerator; an unheated pantry is better.

consumption. Five of the refrigerators were better insulated than the others. Some were located in cool rooms and some in warm rooms. All the boxes had a capacity of about 6 cubic feet, with the exception of one and its capacity was 12 cubic feet. Under farm conditions the refrigerator would not be used to a great extent during the winter months.

The average monthly energy consumption of these refrigerators over a period of a year ranged from 22.6 kilowatt hours in December to 80.3 kilowatt hours in August, a monthly average of 41.9

TABLE 20.—ENERGY CONSUMPTION OF ELECTRIC REFRIGERATORS ON TEN COOPERATING FARMS, 1925-26[1]

(Expressed in kilowatt hours)

Cooperator	1	2	3	4	5	6	7	8	9	10	Average
Location of refrigerator[2]	W	C	C	W	W	W	W	C	C	W	
1925											
September	17	53	24	40	62	52	21	98	13	48	42.8
October	17	16	21	33	25	34	29	48	30	42	29.5
November	21	6	14	26	42	30	25	40	24	47	27.5
December	0	2	14	20	34	27	22	34	21	52	22.6
1926											
January	18	2	10	21	38	32	22	33	30	64	27.0
February	18	0	11	30	35	41	20	34	28	67	28.4
March	20	0	18	34	37	45	31	31	39	60	31.5
April	25	10	18	41	47	40	15	44	45	64	34.9
May	32	49	44	52	60	47	36	76	48	89	49.3
June	35	60	47	58	75	51	39	83	44	40	53.2
July	53	89	72	73	101	75	59	109	64	66	76.1
August	55	84	70	77	114	76	51	131	62	73	80.3
Total annual	311	371	363	505	670	550	380	761	448	672	

[1]The high energy consumption of the refrigerators in the homes of cooperators 2, 5, and 8 during July and August may be accounted for by the fact that considerable ice, sherbet, etc., was frozen. No. 1 disconnected his machine in December. Switch on No. 2 was stuck during February and March, but that was not the fault of the machine. During November, December, and January his machine stayed cool, but the energy record seems to show that the room must have been about the same temperature as the box. Service was needed once on No. 2, 4, 5, 8, and 10. The capacity of each of the boxes was about 6 cubic feet, except that of No. 4, which had a capacity of 12 cubic feet. [2]W = warm room, C = cool room.

TABLE 21.—ENERGY CONSUMPTION OF ELECTRIC REFRIGERATORS ON FOUR COOPERATING FARMS, 1926-27

Cooperator	Number in family	Total energy consumption for year	Maximum energy consumption one month	Minimum energy consumption one month	Average monthly consumption
		kw.hrs.	*kw.hrs.*	*kw.hrs.*	*kw.hrs.*
2	2	423	61—July	13—January	35.2
4[1]	5	283	62—July	15—April	43.6
5[2]	7	350	73—July	23—October	58.3
10	11	530	101—July	11—January	44.0

[1]Used only 6½ months. [2]Used only 6 months.

kilowatt hours for the year, which is determined by dividing the total yearly consumption by 120, the number of customer months (Table 20). The average energy consumption during the summer months was 69.8 kilowatt hours, during the spring months, 38.5 kilowatt hours; fall months, 33.2 kilowatt hours; and winter months, 26.0 kilowatt hours.

From April to September inclusive the ten refrigerators required an average of 56.1 kilowatt hours per month. The highest monthly energy consumption recorded on any one refrigerator under test was 131 kilowatt hours. In practically every case where the energy per month was above 90 kilowatt hours, it was due either to expansion or to discharge valve trouble.

Four of the ten refrigerators were purchased in November, 1926, by the farmers on the test line. The energy consumption of these refrigerators from that time to November, 1927, is shown in Table 21. One of the refrigerators was operated for six months, another for six and one-half months, and the other two for the full year. The energy used monthly averaged 33 kilowatt hours the second year as compared to 41.9 kilowatt hours the first year. The lower monthly consumption the second year is due to the fact that two of the cooperators made use of their refrigerators during summer months only and the average was determined on the basis of the total customer months (48), as in the first case. The maximum kilowatt hours of energy used occurred in July the second year and in August the first year.

Effect of Location of Refrigerator on Energy Used. The location of the refrigerator is a big factor in determining the energy consumed. That less energy is used by a refrigerator in a cool room than one in a warm room is indicated by tests made during the winter months on several similar boxes of the same make, some located in warm rooms and the others in cool rooms.

The difference in the energy consumption of two similar boxes during the warm months is in a large measure due to the difference in the individual users. Some users make a larger quantity of frozen desserts and ice than others, and some users are more careful than others in not putting in hot or warm foods and in covering liquid foods. Undoubtedly these factors determine the energy required to maintain the box at a certain temperature.

That the inside box temperature varied directly with the room temperature was shown by temperature readings on the inside of two refrigerators. One type of refrigerator showed a greater inside temperature variation corresponding with the room temperature variations than the other type. This is illustrated in Fig. 15. No doubt this variation was partly due to poorer insulation, to type of door lining, and to type of door.

The variation in the energy consumption per week could not be traced to any one factor. The number of times the doors were opened did not seem to bear any relation to the energy consumption of the box. The relation of outside humidity, inside humidity, and defrosting to energy consumption could not be determined under the uncontrolled conditions existing on the farms.

Advantages of Electric Refrigerators. The outstanding advantages of electric refrigerators in the farm home are that they save the time ordinarily required in going after ice for an ice box and they make the preparation of frozen desserts, ices, and cool drinks

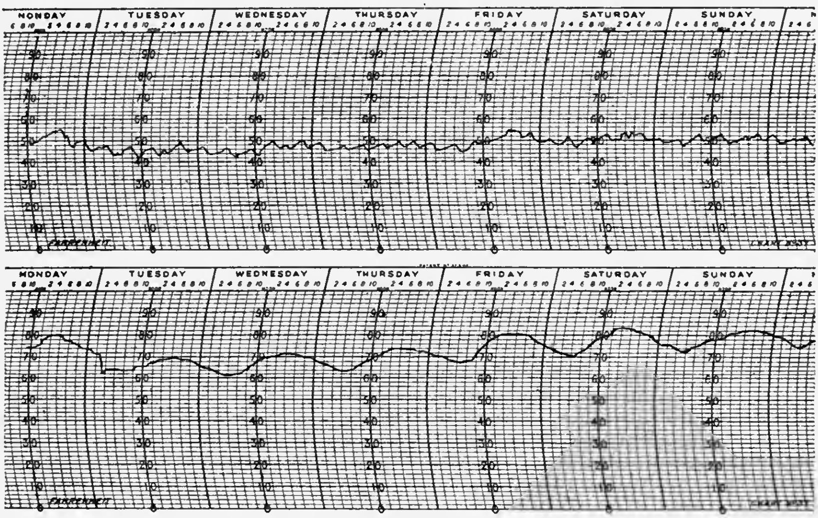


FIG. 15.—CHART SHOWING INSIDE AND OUTSIDE TEMPERATURES OF A REFRIGERATOR

A well-insulated refrigerator box is essential for economy in operation and for the maintenance of a uniform inside temperature.

an easy matter. They also eliminate many of the inconveniences connected with the use of the ordinary ice box. A disadvantage that might be mentioned is that mechanical attention is needed at intervals just as with any other machine, and parts wear out which call for repairs. Most of the refrigerator dealers, however, realize this and provide a service man to take care of these problems.

The domestic refrigerators under test did not fully meet the requirements of the farm homes in the matter of storage space. On the general farm from which cream is sold, only a little cream is produced each day. Over a period of a week, however, these small amounts make as much as 5 or 10 gallons. Under these conditions most farmers would like to have storage space for this amount in

the refrigerator. Sweet cream sells for more than sour cream, thus an added income may be obtained by the use of a refrigerator large enough to store the cream as it accumulates.

Dish Washing

Records were kept on both hand and mechanical dish washing in four farm homes. The time was recorded for collecting the dishes and stacking them away, and a record was made of the number of dishes washed, number of persons served, number of meals served, number of gallons of water used, and the kilowatt hours of energy used.

Two different types of dishwashers were used. One machine forced the water up thru the dishes by means of a paddle at the bottom of the tub. In the other a rotary pump was used that forced the water thru a movable pipe pivoted in the center of the tub.

The dishes were washed with about two gallons of warm or hot water. Soap placed in the water proved less effective in washing the dishes than water containing washing powder. The water was drawn off after the dishes were washed, and about two gallons of hot or boiling water was then used to rinse them. A two-minute period was sufficient for rinsing. Some operators dried the dishes after they were rinsed, but this is not necessary except to polish the glassware.

A summary of the results secured on four farms with these two types of dishwashers is given in Table 22. The time reported as used is in all cases the total time for the entire operation including the washing of the dishes that could not be put into the machine.

In washing dishes by hand the average time used daily varied from 2.7 to 1.53 hours. With the paddle type of machine the average time saved was 22 percent, and with the pump type nearly 28 percent. Where none of the dishes were dried except the glassware (Cooperators 1, 8, and 10), the saving in the operator's time ranged from 22.4 percent with the paddle machine to 41.6 percent with the pump machine. Where the dishes were hand-dried (Cooperator 5), 7.2 percent of the operator's time was saved. It is evident that the larger part of the time reported as saved by the machines is to be credited to the fact that when the dishes were washed by machine, they were not dried by hand.

An average of 34 percent to 51 percent more water was used by the mechanical washer than when the dishes were washed by hand. The energy consumption ranged from 1 to 1.4 kilowatt hours per month for the pump type, averaging 1.2 kilowatt hours. For the paddle type it ranged from 1.6 to 4.8. kilowatt hours, averaging 3.2 kilowatt hours.

The two dishwashers used did not give entire satisfaction because the dishes were not always washed clean and about 20 percent of the

TABLE 22.—TIME AND ENERGY REQUIRED FOR MECHANICAL AND FOR HAND DISH WASHING ON FOUR COOPERATING FARMS

Cooperator	Number in family	Labor time daily by hand[1]	Time saved over hand method based on 1,000 dishes		Percentage of total dishes washed in machine		Water used daily			Energy used monthly	
			Washer 1, paddle	Washer 2, pump	Washer 1, paddle	Washer 2, pump	Hand washing	Washer 1, paddle	Washer 2, pump	Washer 1, paddle	Washer 2, pump
		hours	*perct.*	*perct.*	*perct.*	*perct.*	*gal.*	*gal.*	*gal.*	*kw.hrs.*	*kw.hrs.*
1..........	7	2.70	29.1	30.1	75.0	84.0	6.8	11.0	10.9	3.2	1.2
5..........	7	2.11	7.2[2]	5.0[2]	87.0	75.5	2.7	11.1	6.2	3.2	1.4
8..........	4	1.53	32.1	41.6	85.0	73.2	2.5	4.0	5.4	1.6	1.0
10..........	11	1.66	22.4	34.3	77.7	78.6	6.0	8.2	11.3	4.8	1.2
Average...	7.25	2.00	22.7	27.75	81.17	77.82	4.5	8.57	8.45	3.2	1.2

[1]The time recorded included the total time for collecting, washing, and stacking away. [2]Cooperator 5 hand-dried dishes. The rest of the cooperators hand-dried only the glass dishes and possibly a few others.

TABLE 23.—ENERGY CONSUMPTION OF CHURN[1] WITH ¼-HORSEPOWER ELECTRIC MOTOR

	Total time required for:[2]		Weight of cream	Weight of butter	Energy consumption
	Churning	Working			
	min.	*min.*	*lbs.*	*lbs.*	*kw.hrs.*
Total for year........................	2 515.0[3]	336.0	2 396.70	1 187.30	11.80
Average per month....................	209.5	28.0	199.72	98.94	.98
Average per churning..................	52.4	7.0	49.93	24.73	.24
Average per 100 pounds of butter.......	211.7	28.3	201.7	.....	.99

[1]Capacity of the churn, 12 gallons. [2]Ten minutes was required for washing the butter. [3]The average temperature of the cream was 57.4° F.

total dishes could not be washed in the machines due to the size of the machine or its shape. Stacking the dishes in the pump type of machine was not as easily done as in the paddle type.

The need for about 40 percent more hot water in mechanical dishwashing than in hand washing is an objection from the standpoint of many farm women.

Butter Making

A butter maker similar to a barrel churn, with the exception that it had working rolls, was used by one farmer. The churn had a capacity of 12 gallons and was operated by a ¼-horsepower motor.

For a period of one year a record was taken of the amount of cream churned, the cream temperature, the weight of butter, time required to churn the cream, time required to work and wash the butter, and the energy used. The results are shown in Table 23.

The average weight of cream per churning was 49.93 pounds, from which 24.73 pounds of butter was obtained. The energy consumption averaged .99 kilowatt hour per 100 pounds of butter churned. An average of 7 minutes was required to work the butter and about 10 minutes to wash it. The temperature of the cream varied from 54° to 62° F., averaging 57.4° F. per churning.

The ripening of the cream and the temperature were the two main factors that influenced the time required to do the churning. The cream was kept in a refrigerator until a sufficient quantity was collected to churn. According to expert butter makers, the ideal churning temperature is that at which, when all other conditions are normal, the churning process is completed in about 45 minutes. The average time required per churning with the machine was 52.4 minutes.

In this test cream of a higher temperature was churned in less time than cream of lower temperature. The butter churned from higher temperature cream was softer than that churned from lower cream temperatures. The best was between 58° and 60° F.

The salt water that dripped or was thrown on the exposed metal parts of the machine caused considerable rusting. The metal parts should be covered with suitable paint to prevent this corrosion.

The energy requirement and the cost of operating a butter maker is very slight, and labor is saved over hand methods. With a combination of refrigerator and churn, high-grade butter can be made by the small producer and delivered in reasonably large quantities. The main objection to a butter maker of the type tested was the first cost.

Electricity for Lights and for Minor Household Appliances

Records were kept of the energy consumption for lighting and for minor appliances on each of the ten farms during the three years

TABLE 24.—ENERGY USED FOR ELECTRIC LIGHTS AND MINOR APPLIANCES ON THE TEN COOPERATING FARMS, 1926-27

Cooperator	Total connected light load	Kilowatt hours used each month												Total for year
		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	
	kws.													*kw.hrs.*
1	1.125	37	39	41	34	28	26	34	36	29	37	33	30	404
2	.805	37	22	22	22	36	24	18	15	16	18	20	26	276
3	1.005	67	71	56	41	42	30	25	21	20	25	33	43	474
4	1.285	43	38	43	27	20	28	18	22	32	38	32	34	375
5	1.445	43	42	29	25	30	22	38	20	9	11	17	14	300
6	.535	23	25	22	19	18	16	14	11	12	15	23	19	217
7	1.360	39	45	34	36	25	28	20	18	18	18	24	29	334
8	.830	27	31	27	25	21	21	18	13	20	21	18	23	265
9	.900	22	31	26	19	18	16	14	11	9	14	11	14	205
10	1.415	50	73	71	33	24	20	17	18	31	26	38	40	441
Average	1.070	39	42	37	28	26	23	21	18	20	22	25	27	329

of the test. The energy consumption by months, during one year, for each of the farms, is given in Table 24.

Approximately the same amount of energy was used each year during the test period. The energy consumption of the minor household appliances was practically constant thruout the year; and the seasonal variations shown in Table 24 were due to the increased use of lights during the winter months. The household appliances consisted of such equipment as vacuum sweepers, hand irons, curling irons, fans, battery chargers, heating pads, percolators, grills, table stoves, and dishwashers. While all ten of the cooperators had vacuum sweepers and hand irons, no one cooperator had all of the above equipment.

As a source of energy for lights and for the operation of minor household appliances, electricity is valued by the majority of farmers more than for any other use to which it is put. Since approximately 50 percent of a farmers' time is devoted to work about the farmstead, a large part of which is doing chores in the early morning and in the evening after dark, electric lights save time and reduce the possibility of accidents and fire. They thus fill a very definite need in improving living and working conditions both inside and outside the home.

USES OF ELECTRICITY IN FARM PRODUCTION

This study of the use of electricity for farm operations has been directed exclusively to the application of electricity to the various belt operations employed in farm work and to the furnishing of heat and light. As previously stated, no attempt has been made to adapt electric power to field work.

While a hundred or more uses of electricity on the farm have been mentioned by various investigators, only those of most concern to Illinois farmers were included in this study. A number of other uses investigated at other state experiment stations are listed on pages 474 to 478.

Electricity as a source of power for the productive work of the farm is even less commonly used than in the work of the farm home.

Use of Portable Motor

A problem which faces every farmer who expects to use electricity as a source of power is the proper selection of motor equipment. There are two methods of power drive in general use—the line shaft driving several machines and the direct-connected individual motor. There is little question of the superior merit of the individual drive so far as efficiency and convenience are concerned. In industries it has largely superseded the line shaft. The same is true to a certain extent on the farm. Certain equipment including

pumps, cream separators, milkers, washers, and ironers, that are used many times during the year, are being equipped with direct-connected individual motors. There are other machines, however, used less often and in some instances used only once each season, that are most satisfactorily operated with direct-connected individual motors, but first cost and limited use makes the purchase of individual motors for such machines prohibitive. The portable motor that can be easily moved about and attached is the solution.

Nine portable 5-horsepower motors, equipped with counter shaft having three different-sized pulleys for varying speeds were in use on the experimental line during the three years of this study. When first obtained, only three of the units were equipped with a silent chain to drive the counter shaft, and the other units were equipped with leather belts; however, these were later equipped with chain drives. Each unit was provided with a push-button control switch on the end of a 20-foot cable, an overload temperature relay, and 50 feet of extension cable. A jack was also provided for use in tightening the belt between the portable outfit and the machine driven. A small house was made to protect the motor from rain and snow when it was used outside.

The portable motors were used to advantage in grinding feed, elevating grain, pumping water, sawing wood, mixing concrete, and on one farm a portable unit was used for elevating dirt out of a basement that was being enlarged. Most of the farmers were surprised when they learned how little energy the motors used in doing the various operations mentioned. The chain drive gave better satisfaction than the belt drive. It was possible to obtain four different speeds from the counter shaft with the chain drive, while only three speeds were possible with the belt drive.

The portable motor was one piece of equipment that after the loan period expired was kept by each of the active farmers, altho there were a few objections to it. Under certain conditions it was hard to move around, the leather belt gave some trouble, the push-button control switch grounded rather easily, and the flat extension cable that was used kinked more easily than round cable does when being unrolled for use. Improvements have been made on the units since they have been in use and some of the objections have been eliminated.

The results secured indicate that a portable motor is very useful and the operating expense is very slight when the amount of work done is considered. Such a unit will no doubt play a large part in the future use of electrical power on most farms. It met the needs of the farmstead operations under the methods employed by the ten cooperating farmers. However, a 3-horsepower motor was substituted for one of the 5-horsepower motors on one of the outfits

and it is now being used on one farm, supplying sufficient power for elevating grain, pumping water, mixing concrete, sawing wood, and operating a 4-inch burr mill.

Elevating Ear Corn With Portable Motor

The most efficient results obtained with a drag elevator operated by a 5-horsepower portable motor was on Farm 1. Three thousand two hundred and forty-one bushels of ear corn (243,100 pounds) were elevated 24 feet into a crib with an energy consumption of 21.5 kilowatt hours. The energy required to lift 1,000 bushels 1 foot on the seven outside portable drag elevators ranged from .276 to .588 kilowatt hour. The elevator using the greatest amount of energy required 49 kilowatt hours to elevate 2,929 bushels (219,665 pounds) 28½ feet. The average energy used by the seven elevators to lift

FIG. 16.—ELEVATING CORN WITH OUTSIDE ELEVATOR ON FARM OF COOPERATOR 3

About six minutes were required to elevate a 50-bushel load of ear corn into this 25-foot crib with the use of a clutch-type jack and 5-horsepower portable motor.

1,000 bushels of corn 1 foot was .423 kilowatt hour. The variation in energy consumption was due primarily to the condition of the elevators and the rate of unloading. The range in total lift was from 17.75 feet to 29 feet.

The vertical inside elevator with a 56-foot lift owned by Cooperator X, required .130 kilowatt hour to elevate 1,000 bushels 1 foot, or 19 kilowatt hours to elevate 2,661 bushels (199,560 pounds) 56 feet. The motor was located at the bottom of the elevator but operated the buckets by a separate chain connecting both the top and bottom shafts.

The time required to unload 35-bushel loads from the seven portable elevators was 4 to 10 minutes. Some of the elevators were not

TABLE 25.—ELEVATING EAR CORN WITH DRAG AND VERTICAL ELEVATOR, USING PORTABLE ELECTRIC MOTOR[1]

Cooperator	Period of test	Total running time	Height of elevator	Length of elevator	Total weight elevated	Average running time per load	Average weight of load	Capacity of elevator per hour	Energy used	Energy to lift 1,000 bu. 1 ft.[2]	Number of loads
		hrs. min.	ft.	ft.	lbs.	min.	lbs.	lbs.	kw.hrs.	kw.hrs.	
1	11–12–25 12– 3–25	7 : 19	24	48	243 100	5.3	2964	33 220	21.5	.276	82
2	11–11–25 11–27–25	2 : 30	29	48	110 125	4.6	3337	44 050	19.8	.465	33
3	11–10–25 12–11–25	7 : 39	25½	40	216 490	6.1	2886	28 250	26.0	.352	75
4	11–10–25 11–25–25	4 : 24	20	40	69 360	8.0	2102	15 763	10.0	.540	33
5	11–17–25 12– 1–25	7 : 57	24	42	255 820	5.5	2940	32 382	23.8	.290	87
7	11–10–25 12– 8–25	13 : 19	28½	44	219 665	10.2	2816	16 516	49.0	.588	78
8	11–13–25 12– 9–25	3 : 54	17¾	38	90 750	10.1	3945	23 260	9.8	.455	23
Average of 7 drag elevators		....	.....	..	....	....	....	......	....	.423	..
X[3]	11–19–25	5 : 1	56	56	199 560	3.7	2463	39 785	19.0	.130	81

[1]Cooperator 3 had a 24-foot chain conveyor at the top of his crib. On the farm of No. 7 the elevator was in very poor condition. All elevators had been in use for a number of years. All were of the drag type with bottom drive except that of Cooperator X, which was an inside vertical elevator driven from top and bottom. [2]Weight per bushel figured at 75 pounds. [3]A cooperating farmer not on the experimental line.

fed to full capacity, as considerable seed corn was selected, necessitating a longer period of time to unload.

Portable 5-horsepower motors were used to drive all the elevators. These furnished ample power for doing the work. A 3-horsepower motor was substituted for one of the 5-horsepower motors in 1926 and supplied sufficient power. A clutch type speed jack was used on all the elevators tested. The data secured are summarized in Table 25.

Several special tests were made in elevating individual loads of ear corn, a voltmeter, ammeter, and kilowatt-hour meter being used. It was found that less energy was required for elevating a single load than was used as an average for each of several loads. This reduction in the case of the single load was due to a speeding up of the work when a single test was being made. This would indicate that the 5-horsepower motors were not loaded to their maximum capacity under ordinary conditions and therefore were not being operated to their highest efficiency.

A 3-horsepower motor apparently has sufficient power to handle grain elevating satisfactorily. Only a few minutes are required to elevate a load, as shown in Table 25. It is evident that an electric motor saves time over either the hand method or the horsepower method of unloading grain. Electric power saves little more time than gas-engine power other than in starting. The convenience and ease of control are in favor of the electric drive. Since grain elevating is a seasonal operation, a portable motor that can be used for other work also is highly desirable.

Drying Soft Corn and Small Grain

An early frost in 1924 resulted in a large amount of immature or soft corn. In an effort to find the most practical way to handle this corn with the least amount of spoilage, a cooperative experiment was undertaken by the Departments of Agronomy and Farm Mechanics. Stationary blowers, driven by electric motors to force either cold or heated air thru the corn, were first used. The data obtained in these tests have been published in the Annual Report of this Station for 1924-25, (pages 139 and 140).

During the summer of 1927 a portable oil-burning drier was designed and constructed. This unit consists of an oil-burning furnace and blower mounted as shown in Fig. 17. It was designed for belt drive. The blower draws the combustion gases direct from the oil-burning furnace; the hot gases are diluted with atmospheric air so that the blower delivers the air to the crib or drying unit at the desired temperature.

In March, 1928, this portable drier driven by a 5-horsepower electric motor was used in making two tests to study the value of drying

soft damaged ear corn which had been left in the field all winter. The ear corn was purchased from a farmer near Tolono, Illinois, who harvested it during the second week in March, 1928. It was in such

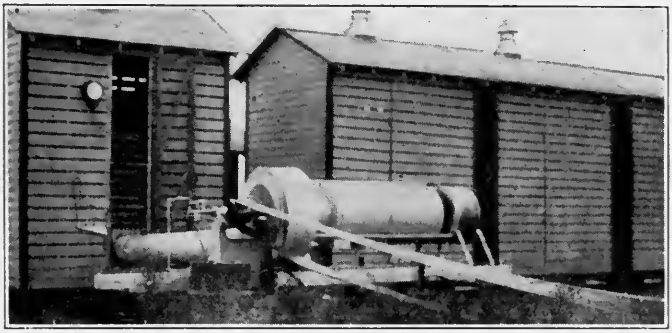


FIG. 17.—PORTABLE DRIER IN OPERATION

The cost of fuel oil and electric energy in drying ear corn with high moisture content with this drier ranged from 2 to 7 cents a bushel depending on the amount of moisture removed.

a poor condition that the local elevator refused to buy it. After sorting, it was found that more than 50 percent of it was in a bad state of decay. However, both the good and the poor corn was dried and even the unsound portion was found to be of sufficient value to justify the drying expense. This corn was dried in a crib with slatted sides

TABLE 26.—DRYING UNSOUND CORN (TEST 1) AND A REASONABLY GOOD QUALITY CORN (TEST 2) USING A PORTABLE DRIER AND 5-HORSEPOWER MOTOR, MARCH 9–15, 1928

	Test 1	Test 2
Quantity of corn, undried, pounds	17 445	13 675
Quantity of corn, dried, pounds	12 345	12 410
Average moisture in grain and cob, undried, percentage	38.8	23.39
Average moisture in grain and cob, dried, percentage	13.5	15.50
Hours of blowing heated air	21	7
Temperature of heated air, degrees F	170–180	160–170
Fuel oil used, gallons per hour	4.97	4.57
Total fuel oil used, gallons	108.16	32
Kilowatt hours of energy used (5-horsepower motor)	79.6	27.6
Cost of fuel oil and electric energy per bushel of dried corn[1]	$.072	$.022
Cost per 1,000 pounds of water removed[1]	$2.57	$3.13
Cost per 1,000 pounds of ear corn (dry basis)[1]	$1.03	$ .32

[1]The figures cover only the cost of fuel oil (8.1 cents a gallon) and energy (5 cents a kilowatt hour).

and a ventilator core in the center into which the air was blown. The results of this work are shown in Table 26.

Owing to the fact that considerable shelled corn was put in with the unsound portion, the air was unevenly distributed and as a result there were spots which did not dry. The higher moisture content of the unsound corn resulted in a lower cost for each 1,000 pounds of water removed but in a higher cost per bushel of dry corn. The 5-horsepower electric motor furnished adequate power and proved to be an economical and practical source of power for the operation of the portable drying unit.

In July and August, 1928, the portable drier was used to dry damp wheat; the power was supplied by a 5-horsepower electric motor. The wheat was dried in batches by placing a layer of the grain on a false floor and then forcing heated air up thru it by means of the portable drier. The false floor was 7 feet by 9 feet in size and was made of slatted construction and covered with screen. Efficient results were secured by blowing the heated air thru an 11-inch depth of grain. Wheat was dried down from 19.2 percent moisture to 13.7 percent moisture at the rate of 34 bushels an hour. The cost of fuel oil and electric energy was 1⅕ cents a bushel of dried grain.

A portable drying unit such as described would be of practical value on many farms for drying seed corn, commercial corn, and small grains. When corn with reasonably high moisture content is stored in an ordinary crib there is always a possibility of spoilage at the center, and by forcing in some heated air, spoilage may be prevented.

Drying Sweet-Clover Seed

On one of the test farms 246 bushels of Grundy county sweet-clover seed were harvested with a combine harvester. It was thought that the seed would be high in moisture content, and equipment was installed in a seed house at Tolono, Illinois, to dry and clean this seed. The equipment consisted of a vertical elevator, a 25-bushel magazine bin, a vertical chute 8 inches by 14 inches by 18 feet, with copper screen baffles spaced 18 inches apart, a blower, a 1-horsepower motor, 1,750 R.P.M., a heater, and a Clipper fanning mill. The heater used was a coal brooder stove. A steel jacket was put around the stove with brooder hover over the top.

The hot air was taken from the lower part of the jacket near the floor, and the fresh air came in from the top and directly over the stove. A slide door and damper was installed in the pipe leading to the blower so as to regulate the temperature of air if needed. A thermometer was installed at the entrance of the hot air into the vertical chute. Another thermometer was installed at the top of the vertical chute.

The rate at which the seed flowed down the chute was controlled by an adjustable door at the foot of the magazine bin. Samples of the seed were taken before and after each batch was run thru the drier, in order to determine the moisture content.

The seed contained a considerable amount of green hulls when it came from the harvester, but practically all of this was removed when it passed thru the fanning mill. The ripe seed was hulled very clean by the combine-harvester and no difficulty was experienced in storing the seed, as the moisture content was between 12 and 14 percent after it passed thru the mill. The amount of material such as light seed, hulls, and foreign material removed by the mill was approximately one-third by weight.

The moisture content of 664 pounds of sweet clover seed was reduced from 13.8 percent to 12.6 percent by blowing heated air thru it for 3½ hours at the rate of 750 cubic feet a minute and at an average temperature of 108° F. The temperature of the heated air as it came out of the shaft was about 92° F.

Another batch of 651 pounds was run for 34 minutes and the moisture content reduced from 12.6 to 11.6 percent by blowing heated air thru it at an average temperature of 135° F. and at a rate of 790 cubic feet a minute. The temperature of the air as it came out of the shaft was about 109° F. The average room temperature in the tests was 87° and 89° respectively.

An average energy consumption of .13 kilowatt hour per bushel was required to operate the fanning mill elevator and blower. About 20 minutes were required to fan and elevate 10 bushels of seed into the magazine and about 20 minutes to empty the magazine. The amount of coke used was so small that it was not recorded. The temperature of 135° F. did not affect the germination of this seed.

To summarize: A very small amount of energy was required per bushel to dry clover seed. However, there would seem to be little need for drying clover seed of less than 14 percent moisture content if it is recleaned by a fanning mill. While the drying of clover seed is hastened by subjecting the seed to high temperatures, germination of the seed is likely to be affected.

Silage Cutting

Two tests were made of the use of electric power for silo filling. A flywheel type of cutter with a throat width of 16 inches was used. It was driven by a 15-horsepower portable motor supplied with power from a portable transformer. The silage was lifted to a height of 36 feet in one test and to 40 feet in the other test. The knives were sharpened and adjusted to proper distance from bar before starting.

The energy required per ton was 1.72 kilowatt hours when the cutter speed was 665 revolutions per minute and the lift was 36 feet.

One and eight-tenths kilowatt hours a ton was used with a cutter speed of 780 revolutions per minute and a lift of 40 feet. The capacities per hour were 8.1 tons and 7.5 tons respectively.

In the first test the fodder was green and fed into the cutter in the form of a bundle. In the second test the corn was in loose form. Considerable trouble was encountered in starting the cutter owing to the high starting torque required. Fuses of 75 amperes were used, which were too small; the starting current reached a maximum of 92 amperes in several trials. When several men pulled on the belt to get the cutter up to speed, the motor pulled the load, but not satisfactorily. In both tests the 15-horsepower motor failed to furnish sufficient power to operate it at the speed at which it was run and at the rate at which it was fed. Either a larger motor or a lower cutter speed would eliminate this trouble. Time did not permit making additional tests.

Three other experiment stations—Minnesota, New York, and Wisconsin—have filled silos successfully with 13-, 15-, and 16-inch cutters driven by 5-horsepower motors. These cutters were operated at reduced speeds, yet an output of 7 to 8 tons an hour was obtained with less than 1 kilowatt hour of energy per ton.[1]

Even tho a 5-horsepower motor slows down the job slightly, it is a decided advantage on many farms to be able to use one of this capacity for ensilage cutting. A smaller crew of men is required to get the corn from the field, and the labor at the machine is used more efficiently. One man can feed a machine cutting 7 or 8 tons an hour with less lost motion than two men can feed a much larger or higher speed machine cutting 12 tons an hour.

Value of Hay Grinding and Chaffing

A study of the value of grinding and chaffing soybean and alfalfa hay for dairy cattle feeding was made in cooperation with the Department of Dairy Husbandry. The soybean hay used was a choice grade of Manchu containing 20 percent of beans and having 18.6 percent moisture content. The alfalfa was from a first cutting and was a uniform lot with coarse stems and a moisture content of 10.6 percent.

The same equipment was used in grinding and the same in chaffing the two kinds of hay. The grinding was done in a burr mill equipped with a cutter-head attachment for roughages. The mill was driven at a speed of 1,170 revolutions per minute by a 20-horsepower motor. The cutter head was driven 720 revolutions per minute. The chaffing

[1]Reports of these tests appear in Committee on Relation of Electricity Bulletin, Vol. 4, No. 1, published by the National Committee on the Relation of Electricity to Agriculture.

TABLE 27.—GRINDING SOYBEAN HAY IN 8-INCH BURR MILL WITH 12-INCH THROAT, EQUIPPED WITH CUTTER-HEAD ATTACHMENT AND DRIVEN BY 20-HORSEPOWER ELECTRIC MOTOR[1]

Test[2]	Running time	Total amount ground	Amount ground per hour	Moisture	Total energy used	Energy per ton	Labor time per ton
	min.	lbs.	lbs.	perct.	kw.hrs.	kw.hrs.	hrs. min.
1	72	850	708	18.0	14	33.0	5 : 39
2	90	1 020	680	18.7	18	35.2	5 : 52
3	70	1 020	874	19.0	10	19.6	4 : 34
4	88	1 020	695	18.5	14	27.4	5 : 44
5	84	1 020	728	19.2	15	29.4	5 : 23
6	84	1 020	728	18.3	16	31.4	5 : 23
Average	..	.....	735.5	18.6	..	29.2	5 : 22

[1]The feeder chain was taken off, and the hay was pushed into the cutter by hand. [2]Period of tests, January to February, 1926, inclusive.

TABLE 28.—CHAFFING SOYBEAN HAY IN 18½-INCH (THROAT WIDTH) ENSILAGE CUTTER, DRIVEN BY 30-HORSEPOWER ELECTRIC MOTOR

Test[1]	Running time	Total amount chaffed	Amount chaffed per hour	Moisture	Total energy used	Energy per ton	Labor time per ton
	min.	lbs.	lbs.	perct.	kw.hrs.	kw.hrs.	hrs. min.
1	31	2 125	4 113	18.30	5.0	4.7	0 : 58
2	42	2 550	3 640	18.70	7.0	5.5	1 : 6
3	47	2 550	3 252	17.75	8.5	6.7	1 : 13.5
Average	..	.....	3 612	18.38	...	5.7	1 : 6

[1]Period of tests, January to February, 1926, inclusive.

was done with an ensilage cutter having a throat width of 18½ inches and driven at a speed of 765 revolutions per minute by a 30-horsepower electric motor. Each outfit required two men to operate it.

The power requirements for grinding and chaffing soybean hay varied considerably with the way in which the hay was fed into the grinder and ensilage cutter. The least energy was consumed when the operator fed the machine uniformly. In order to produce a more even feed into the knives, springs were fastened on the heavy feed roll of the ensilage cutter. The capacity of the ensilage cutter averaged 1.8 tons an hour, while the capacity of the feed grinder averaged .36 ton an hour. The energy required to chaff soybean hay averaged 5.7 kilowatt hours a ton, while grinding soybean hay required an average of 29.2 kilowatt hours a ton. (Tables 27 and 28)

The energy required to chaff and grind alfalfa hay was approximately 40 percent less than the energy required to chaff and grind soybean hay, 3.34 kilowatt hours a ton being required for chaffing, and 18.6 kilowatt hours a ton for grinding (Tables 29 and 30). This reduction in energy was no doubt due partly to the low moisture content of the alfalfa and partly to its finer stems. The capacity of both machines was greater in grinding and chaffing alfalfa hay, owing to the same conditions.

It will be noted that 5.9 percent of the ground alfalfa hay was coarser than 5 millimeters, and 9.3 percent of the soybean hay was coarser than 5 millimeters (Table 31). Of the chaffed alfalfa, 26.2 percent was coarser than 5 millimeters; and of the soybean hay, 74.3 percent was coarser than 5 millimeters. While 17.1 percent of the ground alfalfa passed a ½-millimeter sieve, only 14.6 percent of the ground soybean hay passed the same size sieve; and while 10.1 percent of the chaffed alfalfa passed the ½-millimeter sieve, only 3 percent of the chaffed soybean hay passed this size. It is evident that the alfalfa hay was ground and chaffed considerably finer than the soybean hay even tho the energy required was less.

Whole soybean hay, without treatment, was fed to three groups of 10 cows each, at the rate of 1½ pounds daily for each 100 pounds of live weight, during three five-week feeding periods. The chaffed and ground hay was fed at the rate of 1¼ pounds daily. Refuse, or waste, totaled 13.7 percent for whole hay, 2.4 percent for chaffed hay, and 1.8 percent for ground hay. Refuse in the case of whole and chaffed hay consisted of very coarse stems.

Previous experimental work done by the Dairy Department on soybean straw showed that coarse stems were very low in feeding value. Using this previous work as a basis, it was calculated that the chaffing and grinding of the soybean hay gave a gain of about 5 percent, or 45 pounds and 50 pounds respectively, of digestible dry matter, or an approximate saving of 100 pounds of hay for each

TABLE 29.—GRINDING ALFALFA HAY IN 8-INCH BURR MILL EQUIPPED WITH CUTTER-HEAD ATTACHMENT DRIVEN BY 20-HORSEPOWER ELECTRIC MOTOR

Test[1]	Running time	Total amount ground	Amount ground per hour	Moisture	Total energy used	Energy per ton	Labor time per ton
	min.	*lbs.*	*lbs.*	*perct.*	*kw.hrs.*	*kw.hrs.*	*hrs. min.*
1[2]	88	1 000	681	12.70	9.0	18.0	5 : 52
2	52	850	980	11.70	6.5	15.2	4 : 4
3	90	1 000	666	10.50	9.5	19.0	6 : 0
4	71	1 000	845	10.50	8.6[3]	17.2	4 : 44
5	66	1 000	909	9.20	7.5	15.0	4 : 24
6	75	1 000	800	9.00	9.5	19.0	5 : 0
7	75	1 000	800	11.00	9.5	19.0	5 : 0
8	85	1 000	706	11.70	11.0[4]	22.0	5 : 40
9	72	1 000	833	10.20	11.5[4]	23.0	4 : 48
Average	..	.....	788	10.62	....	18.6	5 : 4.6

[1]Period of tests, June to August, 1926, inclusive. [2]Flywheel on grinder was taken off. [3]New burrs and sharp knives were put on grinder. [4]Knives were dull.

TABLE 30.—CHAFFING ALFALFA HAY WITH 18½-INCH (THROAT WIDTH) ENSILAGE CUTTER DRIVEN BY 30-HORSEPOWER ELECTRIC MOTOR

Test[1]	Running time	Total amount chaffed	Amount chaffed per hour	Moisture	Total energy used	Energy per ton	Labor time per ton
	min.	lbs.	lbs.	perct.	kw.hrs.	kw.hrs.	hrs. min.
1	45	2 550	3 400	12.8	5.00	3.92	1 : 10.4
2	25	2 550	6 125	10.0	3.70	2.90	0 : 39
3	25	2 550	6 125	9.0	4.08	3.2	0 : 39
Average	..	.....	5 216	10.6	....	3.34	0 : 49.5

[1]Period of tests, June to August, 1926, inclusive.

TABLE 31.—DEGREE OF FINENESS OF GROUND AND CHAFFED SOYBEAN AND ALFALFA HAY AS DETERMINED BY AMOUNT PASSED THRU AND RETAINED ON STANDARD SIZED SIEVES

Total number of tests	Kind of hay	Treatment	Size of sample	Amount retained on different-sized sieves					
				Bottom pan	½ millimeter	1 millimeter	2 millimeters	3 millimeters	5 millimeters
			grams	perct.	perct.	perct.	perct.	perct.	perct.
6	Soybean	Ground	300	14.6	10.5	20.5	27.8	17.3	9.3
3	Soybean	Chaffed	300	3.0	2.2	4.3	5.8	10.4	74.3
9	Alfalfa	Ground	300	17.1	12.9	23.8	26.6	13.7	5.9
3	Alfalfa	Chaffed	300	10.1	6.6	19.0	22.1	16.0	26.2

ton fed.[1] About 4 percent, or 80 pounds for each ton fed, was saved by feeding ground and chaffed alfalfa hay instead of whole hay.

The value of chaffing or grinding alfalfa or soybean hay depends largely upon the market value of these roughages. When they are cheap, the cost of chaffing or grinding is greater than the saving in hay and digestible dry matter. When the price of hay is normal, the practice of chaffing is questionable and when the price of hay is high, it may be justified from the standpoint of cost.

From the standpoint of enonomy and feed value, chaffed hay is much more desirable than ground hay. Chaffing gives practically the same feeding value as grinding and requires considerably less labor time and electric energy.

Grinding Grain for Stock Feed

To obtain the best results in feeding grain to dairy cattle and poultry it is essential that it be ground. The problem of grinding grain is therefore one that confronts a large number of farmers. Little is known as to how fine grain should be ground for dairy cows, chickens, hogs, and other livestock in order to get the best results. The practice of grinding grain very fine for general feeding is, however, generally questioned.

FIG. 18.—FEED GRINDER USED FOR GRINDING EAR CORN

Grinding ear corn presents quite a problem to many Illinois farmers. A large hopper or magazine and wagon elevator attachment are desirable from the standpoint of saving time and labor.

In the tests made in this study the energy requirements of several feed mills were determined for grinding different grains to various degrees of fineness when driven by electric motors. A summary of the data secured in testing a 6-inch and an 8-inch burr mill is given in Table 32. The degree of fineness was determined by observation and designated as fine, medium, or coarse. The 6-inch mill was driven at a speed of 550 revolutions a minute and the 8-inch mill at a speed of 970 revolutions a minute. The results show that badly-worn burrs consume 30 to 100 percent more energy than new burrs in grinding the same grain to the same degree of fineness. Burrs are not very expensive and should be replaced when the cutting edges are worn.

[1]See Illinois Agricultural Experiment Station Annual Report for 1925-26, page 90.

TABLE 32.—FEED GRINDING TESTS WITH 6-INCH BURR MILL DRIVEN BY 5-HORSEPOWER MOTOR AND 8-INCH BURR MILL DRIVEN BY 20-HORSEPOWER MOTOR

Test	Kind of grain	Rate of feeding per hour	Size of burrs	Fineness	Energy per 100 pounds
		lbs.	*in.*		*kw. hrs.*
1	Ear corn[1]	540	6	Medium	.449
2	Ear corn[1]	660	6	Medium	.662
3	Ear corn[2]	250	6	Medium	1.310
4	Ear corn[1]	965	6	Coarse	.340
5	Shelled corn	5 670	8	Fine	.339
6	Shelled corn	1 400	6	Fine	.440
7	Shelled corn	995	6	Fine	.478
8	Shelled corn	630	6	Fine	.660
9	Shelled corn[2]	785	6	Medium	.476
10	Oats	2 220	8	Fine	.772
11	Oats	486	6	Fine	.770
12	Oats	360	6	Fine	.800
13	Oats	746	6	Medium	.401
14	Oats[2]	175	6	Medium	2.500
15	Wheat	1 302	6	Fine	.410
16	Wheat	1 500	6	Fine	.418
17	Wheat[2]	1 050	6	Medium	.571
18	Soybeans	900	6	Medium	.720
19	Soybeans[2]	640	6	Medium	.941

[1]High moisture content. [2]Dull burrs.

TABLE 33.—SUMMARY OF FEED GRINDING TESTS WITH TWO SMALL-SIZED HAMMER MILLS

Test	Kind of grain	Rate of feeding per hour	Size of screens	Fineness		Energy used per 100 pounds
				Standard modulus	Determined by observation	
		lbs.	*in.*	*index no.*		*kw. hrs.*
	2 hp. motor, 1,900 r.p.m.					
1	Shelled corn	160	1/16	2.90	Medium	1.634
2	Shelled corn	345	1/8	3.33	....	.692
3	Shelled corn	690	3/16	3.88	....	.254
4	Shelled corn	1 760	1/4	4.37	Coarse	.129
	5 hp. motor, 3,900 r.p.m.					
5	Shelled corn	1 040	1/4	....	Medium	.550
6	Oats	947	1/4	....	Medium	.820
7	Soybeans	941	1/4	....	Medium	.590

Ear corn high in moisture content causes considerable trouble in bridging or clogging the hopper in a 6-inch burr mill. More power is also required to grind it than corn of low moisture content. The addition of a cob crusher to one of the 6-inch burr mills used by one of the cooperating farmers remedied the trouble of bridging to a great extent. That a mixture of some grains often aids the process of grinding was also found. Soybeans, for example, when ground alone tend to cake on the burrs and generally clog the mill or reduce the capacity. The mixing of shelled corn or oats with soybeans results in a better grinding than when the soybeans are ground alone.

Tests with two small hammer mills are reported in Table 33. In four of the tests the degree of fineness was determined more precisely by a method recently adopted by the American Society of Agricultural Engineers.[1] It is evident from these tests that grain that is ground fine requires more energy than when it is ground coarse. One of the mills required 12.5 times as much energy to grind shelled corn fine when using the 1/16-inch screen as when grinding it coarse with a 1/4-inch screen. It is also evident from the tests with these two hammer mills that the speed of the hammers (revolution per minute), as well as the size of screen used, determines the fineness of grinding.

In general both the hammer and burr types of mills give satisfactory results in grinding feed. The hammer type of mill is especially adapted for fine and medium grinding. With the proper size of screens this type of mill operated at a sufficient speed will grind grain to practically any degree of fineness. There are no burrs to replace and no parts especially exposed to wear, and thus there is little upkeep expense and little reduction in efficiency with use. The hammer mill is not easily injured by foreign materials in the grain or by running empty, and it is therefore adaptable to automatic control when driven

[1]Until recently there have been no definite standards with which to describe the degree of fineness to which grain has been ground. Since it is more expensive to grind feed fine than to grind it coarse, it is important that definite standards be generally recognized. Furthermore, a standard method of reporting the degree of fineness by sieve analysis would make possible more accurate comparison of results of feed grinding tests and feeding experiments. The Rural Electric Division of the American Society of Agricultural Engineers recently adopted the following method for this purpose: A 250-gram sample of ground grain, or in the case of forage a 100-gram sample, is oven-dried at 100° Centigrade to constant weight. The sample is then placed on the coarsest of a group of standard Tyler 8-inch screens of the following sizes: 3/8-inch, and Nos. 4, 8, 14, 28, 48, and 100, and is shaken for five minutes with a Ro-tap shaker. The degree of fineness is then determined by recording the accumulative percentages of the material retained on the several screens beginning with the coarsest. The modulus (or measure) of fineness is equal to the sum of these percentages divided by 100. Thus the fineness modulus ranges from 0 for a feed all of which passes thru the 100-mesh, or smallest screen, to 7.0 for feed all of which is retained on the 3/8-inch, or largest, screen. The finer the product is ground the smaller the index number.

by an electric motor. Most of the burr mills meet the requirements for medium and coarse grinding. They are also satisfactory for grinding ear corn. The two types compare quite favorably as to energy requirements.

With either the burr or the hammer mill the energy required and the rate and quality of grinding are affected by the kind, quality, and moisture content of the grain. With other conditions the same, oats require the greatest amount of energy per hundred pounds ground and shelled corn the least; barley and soybeans range between. With the hammer mill the fineness of grinding depends largely on the size of the screen, the rate of speed, and the rate of feeding. With the burr mill the fineness of grinding depends on the set and condition of the burrs, the speed, and the rate of feeding.

The results of these tests with feed grinders bear out the following established facts:

1. Worn burrs consume an unnecessary amount of energy.
2. More energy is required where the grain is high in moisture content.
3. Finely ground grain requires considerably more energy than medium or coarsely ground grain.
4. Ear corn with high moisture content clogs the hopper in a 6-inch burr mill more than does dry ear corn. This is remedied to some extent by the use of a cob crusher.
5. Unless ear corn is well broken up or crushed before being put into a small hammer mill, the speed of grinding is greatly reduced and an undue amount of energy is used.
6. A small feed grinding unit is practical for many farms.

Oat Hulling

There are several factors that affect the results of hulling oats such as the uniformity of the oats, moisture content, weight per bushel, the speed of the machine, and the air and feed adjustment of the machine. While the moisture content and weight per bushel are important factors affecting the hullability of oats, no doubt the uniformity of the oats is the most important factor.

In this study three different types of oat hullers were operated and tested under various adjustment in cooperation with the Animal Husbandry Department of the University. Two machines were of the same type but of different capacities. The groat, or oat kernels, were fed to hogs by the swine division to determine their value when included in a ration of corn and protein supplement. A number of different combinations of adjustments were tried on four different machines. The best results obtained are given in Table 34.

The impact method was used to remove the hulls from the kernel. On Machines 3 and 4, screens and a fan were used to reduce the losses.

TABLE 34.—SUMMARY OF OAT HULLING TESTS MADE ON FOUR MACHINES OPERATED BY A 5-HORSEPOWER MOTOR[1]

Machine	Capacity rating per hour	Operating capacity per hour	Huller speed	Moisture content	Weight per bushel	Quantity of groat or oat kernel: Available	Recovered: Hulled		Recovered: Unhulled		Total loss		Energy per 100 bushels
	bu.	bu.	r.p.m.	perct.	lbs.	lbs.	lbs.	perct.	lbs.	perct.	lbs.	perct.	kw.hrs.
1.	12–20	22.9	3 000	12.00[2]	34	23.02	16.17	70.2	3.40	14.8	3.45	15.0	17.20
2.	25–35	16.9	2 600	12.15	29	19.60	12.40	63.2	3.59	18.3	3.61	18.5	15.70
3.	40	39.2	2 575	12.15	29	19.60	14.30	73.0	3.64	18.6	1.66	8.4	9.17
4.	40–50	75.0[3]	2 125	12.00	27	18.00	10.20	56.7	5.41	30.1	2.39	13.2	9.60

[1]These data were picked from a dozen different combinations of adjustments as to rate of feeding, air, and speed of machine, because they gave the most satisfactory results. Better results might have been obtained from other combinations not tried. [2]Estimated. [3]Motor was overloaded at this capacity.

TABLE 35.—TESTS OF TWO MILKING MACHINES OF TWO SINGLE UNITS EACH

Machine	Size of motor	Running time	Average number of cows	Average time per cow daily	Total wt. of milk by machine	Total wt. of milk stripped	Total wt. of milk produced	Av. wt. of milk per cow daily	Av. wt. of milk stripped per cow daily	Total energy used	Energy used per cow daily	Energy used per 100 lbs. milked	Average time per day for cleaning machine
	h.p.	hrs.		min.	lbs.	lbs.	lbs.	lbs.	lbs.	kw.hrs.	kw.hrs.	kw.hrs.	min.
1.	¾	437.2[1]	10.01	7.19	98 605	11 624	110 229	30.22	3.18	328.8[1]	.09	.33	18.0
2.	½	289.4[2]	8.18	7.07	38 456	6 517	44 973	18.34	2.66	202.0[2]	.08	.52	20.5

[1]Record kept for one year. [2]Record kept for ten months.

An increase in huller speed above a certain number of revolutions per minute resulted in more finely cracked kernels and in most cases a greater loss occurred. This was very evident with the first two machines, where no screens were used. By mixing light oats with heavy oats, the effect of lack of uniformity was obtained. In hulling this sample it was very difficult to reduce the losses to a minimum and still secure groat free from whole oats and hulls. Whole oats contain about two-thirds groat, or oat kernel. The percentage of groat lost with hulls varied from 8.4 percent to 18.5 percent, and the percentage of the groat obtained that was actually hulled ranged from 56.7 to 73.0. A higher percentage of groat free from whole oats and hulls was obtained, but the losses were very heavy. The same quality and grade of oats were not available for all the tests, which partly accounts for the differences in results.

Whether or not it will pay a farmer to hull oats that are to be fed to hogs is partly a question of the extent to which the nutritive value of the oats is increased. On this point the following paragraph taken from the Annual Report of this Station for 1926-27 (page 80), is of interest (the oats were included in a ration with corn and protein supplements):

"Whether hulling oats will pay more than feeding them finely ground will depend upon the proportion of oats fed and the cost of the two operations. When the two were fed in the ratio of 1 to 4 with corn, oat kernels were worth from $1.21 to $2 a hundred pounds more than finely ground oats were worth when fed under similar conditions and calculated to the same price schedule."

Milking With Machines

Data were secured on two pipe-line types of milking machines used by cooperators on the experimental line. One machine was driven by a ¾-horsepower motor and the other by a ½-horsepower motor; each operated two single units. One machine was used in milking 10 cows and the other, 8 cows. The operating time, number of cows milked, total weight of milk produced, total weight of milk stripped by hand, time required to clean machines, and the energy required was recorded for a period of 12 months on one farm and 10 months on the other farm. To determine the time saved by use of the machines, a record was also secured of the labor required to milk these two dairy herds by hand. A summary of the results secured in using the two machines is given in Table 35.

The first machine required an average of 27.4 kilowatt hours a month to milk 10 cows producing an average of 30.22 pounds of milk a day. The energy consumption ranged from 33 kilowatt hours in November to 22.8 kilowatt hours in July. This difference in energy consumption was due in part to the stiffness of the oil in the pump caused by cold weather.

The range in energy consumption per 100 pounds of milk drawn was .47 kilowatt hour when the cows were producing an average of 25.2 pounds a day to .24 kilowatt hour when they were producing an average of 35.6 pounds a day. The average was .33 kilowatt hour per 100 pounds of milk drawn, as shown in the table. The effect of the variation of milk flow on the kilowatt hours of energy used is illustrated in Fig. 20. A decline of 31.6 percent in the milk flow coincided with an increase of 95 percent in energy consumption per 100 pounds of milk drawn.

The care of the first machine required an average of 18 minutes a day. It was cleaned by drawing cold and hot water thru the units after the evening's milking and thoroly washing it with hot water

FIG. 19.—MILKING MACHINE IN OPERATION ON FARM OF COOPERATOR 4

About 50 percent of the labor that was required when milking by hand was saved by the use of this mechanical milker.

after the morning's milking, using washing powder and brushes. The vacuum pipe line was cleaned once or twice each month. It is essential that the milking machine be carefully cleansed in order to produce milk with a low bacterial count.

The second machine required an average of 20.2 kilowatt hours a month to milk 8 cows producing an average of 18.34 pounds of milk a day. The energy consumption ranged from 15 kilowatt hours in January to 25 kilowatt hours in July. This variation was due largely to the quantity of milk produced. The variation in energy consumption was from .87 kilowatt hour per 100 pounds of milk drawn when the cows were producing an average of 14.3 pounds of milk a day to .35 kilowatt hour when they were producing an average of 24.5 pounds a day. The average was .52 kilowatt hour per 100 pounds of milk. A decrease of 69 percent in milk flow caused an increase of 148 percent in the energy required to draw 100 pounds of milk. The care of this machine required an average of 20 minutes a day.

With the first machine 9 minutes of one man's time was required per cow per day to do the milking (including cleaning time), while 20.4 minutes of one man's time was required to do the milking by hand. With the second machine 9.6 minutes of one man's time was required per cow per day, while 17.6 minutes was required to do it by hand.

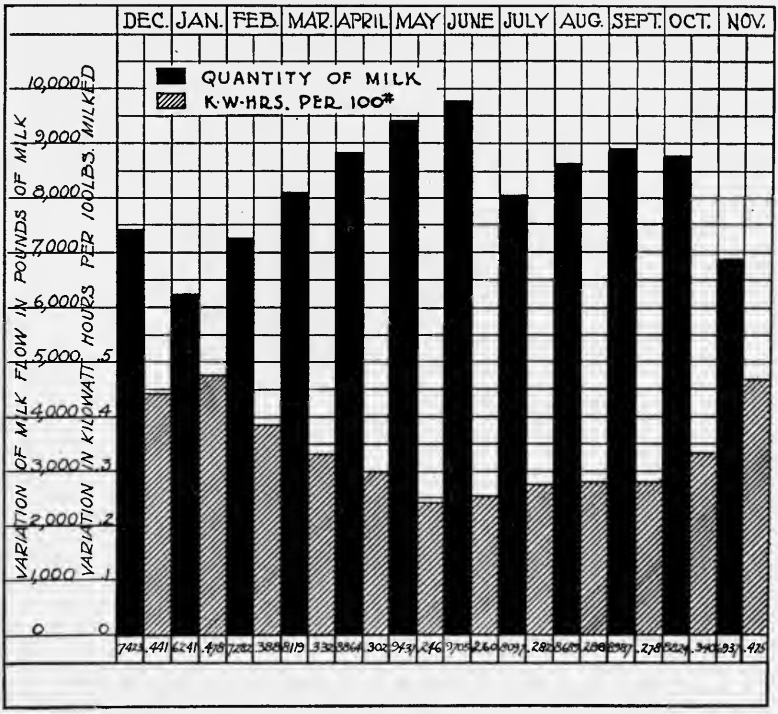


FIG. 20.—VARIATIONS IN ENERGY REQUIRED FOR MILKING

The above graph represents the records obtained on a herd of 10 cows, a 2-unit milking machine with a ¾-horsepower motor being used. The energy consumption per 100 pounds of milk drawn ranged from .47 kilowatt hour when the cows were producing an average of 25.2 pounds a day to .24 kilowatt hour when they were producing an average of 35.6 pounds a day.

In both cases the saving of labor time was approximately 50 percent.

The first machine drew 89 percent of the total milk produced and the second 85 percent. It was not practical to leave the milker on the cow any longer than required to draw all but 1 to 1.5 pounds of milk. The milking operation can be speeded up considerably if this practice is followed or even if the unit is removed sooner.

A third pipe-line milker used on a herd of 20 cows on a farm not on the experimental line was investigated in an attempt to reduce the

energy consumption by changing the size and location of the pumping unit. The results are recorded in Table 36.

The machine as purchased and installed by the farmer included a 4-unit pump and a 5-horsepower motor. This equipment was located in a building about 75 feet from the barn. During the first period of the test, records were kept of the energy consumption and the milk drawn for a period of one month with the arrangement as it was found on the farm. Under this original arrangement the energy consumption for each 100 pounds of milk was 1.38 kilowatt hours. The pump was then moved to the barn and a 3-horsepower motor substituted for the 5-horsepower motor. Records were kept for two additional months with this installation. The energy consumption per 100 pounds of milk was 1.02 kilowatt hours, a saving of .36 kilowatt hour. There are four

TABLE 36.—INFLUENCE OF LOCATION AND SIZE OF PUMP AND MOTOR ON ENERGY CONSUMPTION OF MILKING MACHINES FOR EACH 100 POUNDS OF MILK DRAWN FROM TWENTY COWS

Size of equipment	Milk drawn per month	Energy used per month	Energy used per 100 pounds drawn
	lbs.	*kw. hrs.*	*kw. hrs.*
Four-unit pump, 5 hp. motor[1].....	9 828	135.5	1.38
Four-unit pump, 3 hp. motor......	15 382	157.3	1.02
Two-unit pump, 3 hp. motor......	13 734	97.8	.71
Two-unit pump, 2 hp. motor......	10 040	72.0	.72

[1]Pump and motor were located about 75 feet from the barn during this test. This was the original location of the pump when it was driven by a gasoline engine. The high energy consumption prompted this study. The other three tests were made with the equipment located in the barn near the pipe line.

factors that affected this saving—the change in the location of the pump, the change in the size of the motor, warmer oil, and increased milk flow.

A 2-unit pump of the same make was then secured and substituted for the 4-unit pump and records were kept for another two-month period when operated by the 3-horsepower motor. The energy consumption for each 100 pounds of milk drawn was reduced to .71 kilowatt hour, a saving of .31 kilowatt hour over the previous installation. This reduction can be attributed to the change in the size of the pump, since the motor was the same and the other factors were kept practically constant.

A fourth test was made with the 2-unit machine operated by a 2-horsepower motor. The energy consumption during this test, for each 100 pounds of milk drawn, was .72 kilowatt hour. Milk production declined 28 percent as compared with the amount produced during the previous period. It is evident that if the milk production had remained constant, the energy requirement for each 100 pounds of milk drawn

during this test would have been less than during the preceding test. However, when compared with the results obtained in the first test with the 4-unit pump and 5-horsepower motor, there is a saving of .66 kilowatt hour per 100 pounds of milk, or practically 50 percent. This saving may be largely attributed to the change in equipment, as all factors were nearly constant except for the warmer oil during the fourth test period. The total amount of milk drawn during each test period, also the energy used per month, and the energy consumption for each 100 pounds of milk drawn with the various kinds of equipment used is shown in Table 36.

TABLE 37.—ENERGY CONSUMPTION OF NINE CREAM SEPARATORS ON TEST FARMS

Cooperator	Capacity of separator per hour	Rating of motor	Length of record	Total milk separated	Energy used		Average energy per month
					Total	Per 100 pounds	
	lbs.	*h.p.*	*mos.*	*lbs.*	*kw. hrs.*	*kw. hrs.*	*kw. hrs.*
1........	850[1]	1/6	12	23 321	9.80	.042	.81
2........	450[2]	1/6	9	11 272	6.95	.061	.77
3........	1 000	1/6	11	60 576	24.70	.040	2.24
4........	1 000	1/6	9	19 822	8.80	.044	.97
5........	750	1/6	6	15 338	9.00	.058	1.50
7........	750	1/8	12	37 976	19.20	.050	1.60
8........	650	1/6	12	37 178	15.80	.042	1.31
9........	650	1/6	11	26 641	11.00	.041	1.00
10........	750	1/6	9	24 238	14.30	.059	1.59
Average...	...	..	..	28 483	13.28	.047	1.31

[1]A 500-pound separator with 1/6 horsepower was used for two months. [2]A 600-pound separator with 1/3 horsepower was used for four months.

The results of this study of milking machines emphasizes the following points:

1. To reduce energy consumption, the pump should be located as near to the active pipe line as possible.

2. During the winter months the oil in the crank case of most pumps should be thinned with kerosene, or a light grade of oil should be used to reduce the energy requirements.

3. Petcocks properly installed will eliminate considerable trouble experienced by the freezing of condensed moisture during low temperature.

4. Temperatures lower than 10° F. sometimes cause the pulsators to stop operating.

5. Energy consumption may be reduced to a minimum by carefully selecting equipment of proper capacity for a particular condition.

Cream Separating

Records were kept on nine electric-driven cream separators varying from 450 pounds to 1,000 pounds capacity. The weight of the milk each day and the energy used each month was recorded for a period of one year.

In these tests the energy consumption per 100 pounds of milk separated ranged from .040 to .061 kilowatt hour, averaging .047. The monthly average per farm for the year 1925-26 varied from .77 to 2.24 kilowatt hours, averaging 1.31 per month of actual use. During 1926-27 the monthly average per farm varied from .80 to 1.38 kilowatt

FIG. 21.—CREAM SEPARATOR AND WASHING MACHINE OPERATED BY ELECTRIC MOTORS

With machines that are used daily or weekly thruout the year, the use of a small electric motor results in considerable saving of labor.

hours, averaging 1.19 for all farms. The energy required to separate 100 pounds of milk decreased as the total quantity of milk separated per day increased.

Table 37 gives a summary of results obtained with these tests on cream separators. The curves in Fig. 22 give a better idea of the way in which energy requirements are affected by variations in the amount of milk separated. Since data from which these curves were plotted were not secured under controlled conditions, they should not be considered as representing the true characteristics of all cream separators but simply as indicative of what may be expected under farm operation.

All the curves in Fig. 22 show that a decrease in total milk separated will cause an increase in energy consumption per unit of work done. It is to be noted from Curve 1, however, that after a certain

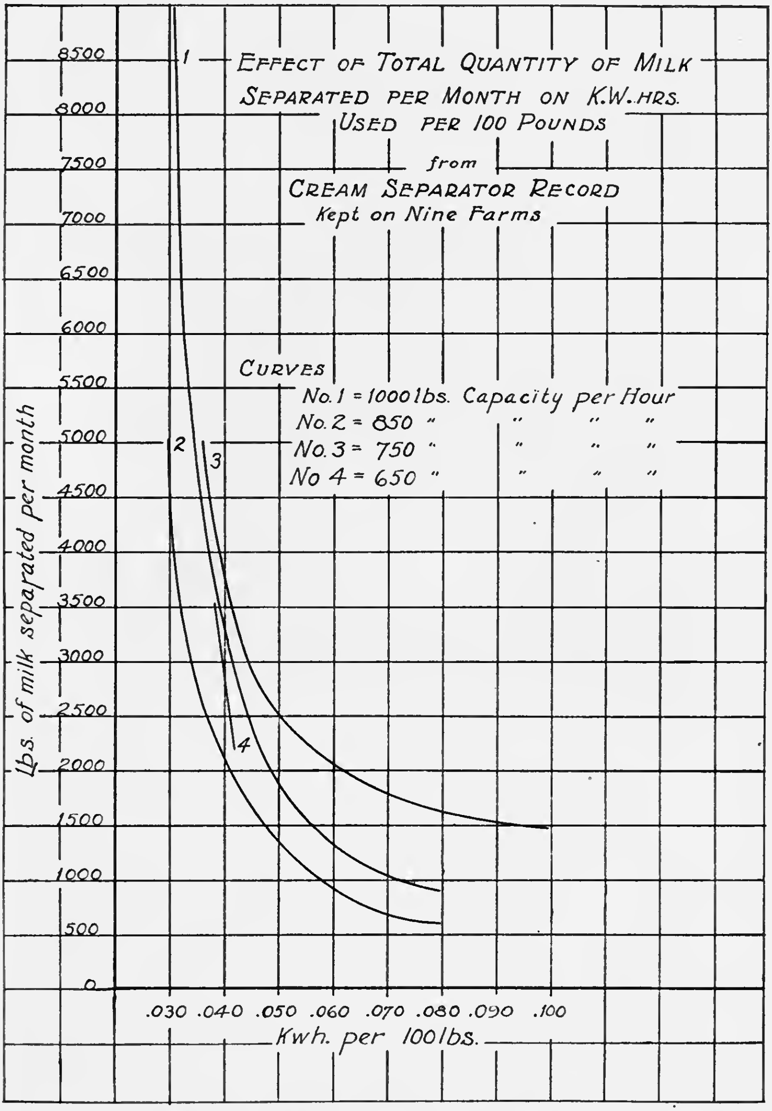


FIG. 22.—RECORD OF ELECTRIC CREAM SEPARATORS ON NINE FARMS

The greatest efficiency in the use of electric energy in operating a cream separator is obtained when large quantities of milk are separated. In 1926-27 the monthly average kilowatt-hour consumption per farm was 1.19.

point has been reached, there is no appreciable decrease in the energy consumption per unit of work done. This is due to the fact that the motor on the separator consumes considerable energy in getting the bowl up to the proper speed, but after the bowl has reached its required speed, the energy consumed is much less and remains about constant. When a large quantity of milk is run thru the machine, the energy consumed in starting the bowl is small in proportion to the total energy used. If a small amount of milk is separated, the amount of starting current used is large in proportion to the total and results in an increased amount of energy to 100 pounds of milk separated, as is indicated by the lower part of the curve.

An electrically operated cream separator is run at a more uniform speed than a hand-operated machine, and it therefore does a more efficient job. The energy used by the motor, as shown in these tests, is so slight that the actual cost of operation is almost negligible. Since the cream separator is used a large number of times during the year, the use of a small electric motor drive is a great convenience, results in considerable saving of labor, and is greatly appreciated by farmers who have electric power available for such an application.

Deep-Well Pumping

In order to study the power requirements for pumping water from a deep well, measuring equipment and electric-driven pumps were installed on two of the cooperating farms.

On Farm 3 a hydropneumatic water system was installed with provisions made to pump water to a stock tank in case the windmill failed to operate the deep-well pump connected to another well. A manually operated ¾-horsepower motor drove the pump jack, which was connected to a well about 150 feet deep with a 2-inch casing. The home was equipped with a kitchen sink, lavatory, and laundry equipment. The energy required to pump 1,000 gallons of water with a pressure range at tank of zero to 50 pounds was 2.61 kilowatt hours.

On Farm 10 a ½-horsepower motor was used to pump water from a 150-foot, 2-inch drilled well into an open attic gravity tank located on the third floor of the house. Water was also pumped directly into a stock tank located close to the well. During the summer months water was pumped into the gravity tank and then out to a stock tank in the pasture. The energy required to pump 1,000 gallons of water was 2.67 kilowatt hours.

The water level on Farm 10 was approximately 35 feet from the surface and on Farm 3, 25 feet from the surface.

Painting With a Paint Spray Machine

A paint spray machine consisting of a pressure pump operated by a 1½-horsepower motor and a pressure tank mounted on trucks, and

TABLE 38.—OPERATING ELECTRIC PAINTING MACHINE USING INEXPERIENCED OPERATORS, 1925-27

Building	Number of coats	Area painted	Amount of paint used	Weight per gallon	Total gallons used	Total time used	Time required to clean machine	Time used per 100 sq. ft.	Area covered by 1 gal. paint	Energy used: Total	Energy used: Per 100 sq. ft.
		sq. ft.	lbs.	lbs.		hrs. min.	hrs. min.	hrs. min.	sq. ft.	kw.hrs.	kw.hrs.
Barn 1[1]	1st	3 900	148.0	10.0	14.80	21 : 30	1 : 30	0 : 33	263.0	44.0	1.130
	2d	3 900	236.0	11.5	20.50	12 : 30	0 : 30	0 : 19	190.0	12.0	.308
	Total	7 800	384.0	10.7	35.30	34 : 00	2 : 00	0 : 26	220.0	56.0	.720
Barn 2	2	3 976	124.7	13	9.60	13 : 36	......	0 : 20	414.0	17.0	.430
Poultry house	2	1 646	59.0	13	4.50	4 : 58	......	0 : 18	368.0	5.7	.340
Laboratories	1	25 440[2]	1 664.0	13.5	123.20	102	5 : 00	0 : 24	207.3	84.0	.330
House[3]	1st	1 790	57.0	12	4.75	7	......	0 : 23	378.0	8.0	.44
	2d	1 790	42.0	12	3.50	55	......	3 : 4	512.0	....	....

[1]Barn in very poor condition. Farmer did the painting. [2]Of this area 3,240 square feet was brick wall. [3]First coat was painted by machine, second coat by hand.

accessories, was used to paint a house, two barns, a poultry house, and the laboratories in the Farm Mechanics Building at the University of Illinois. A record was taken of the total area covered, the time used, the amount of paint used, the weight of the paint to a gallon, and the energy used. Inexperienced men operated the spray nozzle, or gun, on each building. Table 38 shows the results obtained in this test.

Fifty feet of air hose and 25 feet of paint hose were connected to a 5-gallon paint container. A 1-gallon paint can may be used inside the 5-gallon container when small quantities of paint are to be used. The pressure on the paint and air at the gun nozzle is controlled by separate valves. By the use of the full length of air hose and the paint hose, a working range of 75 feet from the machine was obtained. In operating the machine a working pressure of about 35 to 40 pounds is used to force the paint into the pores of the lumber. The paint

FIG. 23.—ELECTRIC PAINTING MACHINE IN OPERATION

Five hours of labor were required to paint this poultry house with two coats. The area painted included 1,646 square feet. The electric energy used averaged .34 kilowatt hour for each 100 square feet covered once.

pressure varies slightly, depending on the height of the gun above the paint container. Paint of almost any consistency can be applied on a building with this type of machine.

Barn 1 was painted twice with the machine. The surface was in very poor condition and required a great deal of paint to cover it. Considerable oil was used in the paint for the first application. In applying this first coat an average of 33 minutes was required to cover 100 square feet of area, whereas the second coat required only 19 minutes for such an area. One gallon of paint covered an average of 220 square feet of barn surface. The average energy consumption to 100 square feet of surface painted, taking into consideration both coats, was .72 kilowatt hour.

The surface of Barn 2 was in fairly good condition before painting. The average time required to apply two coats of paint was 20 minutes to 100 square feet of surface. Four hundred and fourteen square feet were covered with 1 gallon of paint. The energy consumption was .43 kilowatt hour to 100 square feet of surface painted.

The laboratories in the Farm Mechanics Building had never been painted and a considerable part of the wall surface was brick. The operating speed was considerably reduced by the many pipes and windows and equipment on the floor. Shields were used when painting the windows but considerable paint was sprayed on the glass. The glass was covered with a cleaning powder before the painting started. Considerable paint dust was noticed on the floor after finishing but could be swept up with a broom. The average time required to paint 100 square feet was 23 minutes. Two hundred and seven square feet of surface was covered with 1 gallon of paint. The energy consumption to 100 square feet covered was .33 kilowatt hour.

A house was painted with a combination of spray machine and hand labor. The first coat was applied with the machine in 7 hours, or at the rate of 23 minutes to 100 square feet of area. Eight kilowatt hours were used for the job, or an average of .44 kilowatt hour to 100 square feet painted. The windows and doors were trimmed by hand. The second coat was applied by hand in 55 hours, or at the rate of 3 hours 4 minutes to 100 square feet. The hand painting was done by a young man who had some experience assisting his father in painting during the summer months.

One gallon of paint applied by the machine covered 378 square feet, first coat; whereas 1 gallon covered 512 square feet, second coat, when applied by hand.

The total cost to paint the house with the machine, including hired labor, was $65.25 against $148.48, the contractor's estimated price.

The paint spray machine evidently offers the possibility of considerable saving of time. Furthermore paint can be forced into cracks where the brush cannot possibly reach. Paint can be applied as uniformly with the machine as with a brush after the operator has some experience, and there need be no waste. The cost per unit area of surface covered is very low compared to contract jobs done by hand.

The main objection to a paint machine is the first investment. Painting is ordinarily done about once in every four or five years, which means that a considerable investment is tied up in such a machine. This objection may be overcome by several farmers purchasing a machine cooperatively.

Lighting Poultry Houses

The use of electric lights in the poultry house during the winter months as a stimulant for egg production was tried out on two of the experimental farms.

The lighting units were 40-watt Mazda lamps with a cone-shaped reflector 16 inches in diameter by 4 inches high. They were hung 6 feet from the floor and 10 feet apart. The poultry houses that had partitions were figured as separate pens and the number of lighting units required was determined by allowing 200 square feet of floor space for each unit. This intensity of light was found to be sufficient. The lights were turned on early in the morning so as to lengthen the

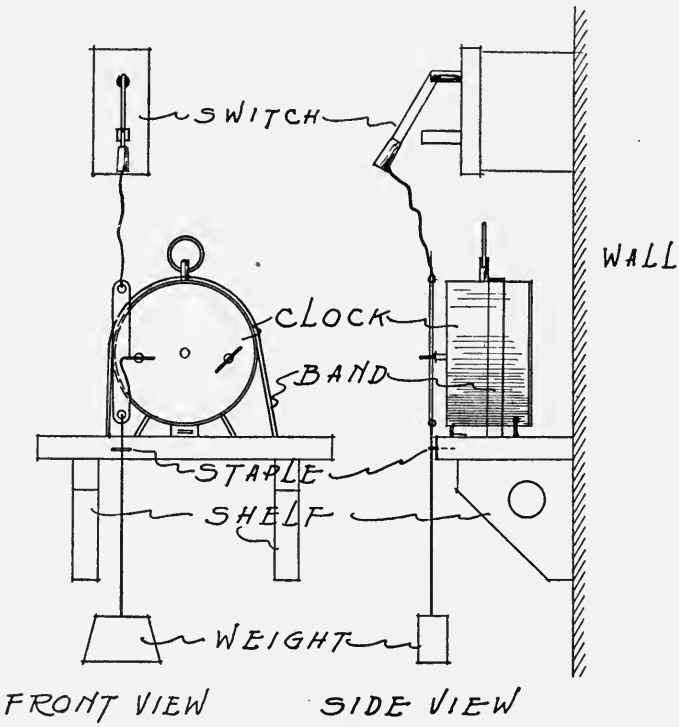


FIG. 24.—DEVICE FOR AUTOMATICALLY TURNING ON POULTRY HOUSE LIGHTS

The lights were turned on automatically early in the morning so as to lengthen the hen's working day to about 12 or 13 hours.

hens' working day to about 12 or 13 hours. A knife switch, closed by a weight which was released by a cheap alarm clock, was used to turn on the lights (Fig. 24).

On the farm of Cooperator 2 only pullets were used. The test period on this farm was from December 22 to April 1. The following table gives the principal facts:

Total number pullets in pen	172
Eggs produced	7,773
Percentage of pullets laying each day	44.7

Value of egg sales	$196.72
Cost of feed and lights	89.73
Return above cost of feed and lights	106.99
Return per pullet above cost of feed and lights	.62

The feed consisted of a mash having equal parts of corn, wheat, oats, meat scraps, and a little salt; a scratch grain made of 5 parts corn, 3 parts wheat, and 2 parts oats; and oyster shell plus a small amount of green feed. The average energy consumption averaged 9 kilowatt hours monthly for 100 birds.

On the farm of Cooperator 8 there was one pen of pullets and one pen of hens. The test period extended from December 3 to March 25. Following are the main items of interest:

Total number of pullets in pen	149
Eggs produced	6,725
Percentage of pullets laying each day	40.0
Value of egg sales from pullets	$186.40
Total number of hens	123
Eggs produced	3,784
Percentage of hens laying each day	27.21
Value of egg sales from hens	$104.87
Total egg sales	291.27
Total cost of feed and light for both pens	136.54
Return above cost of feed and lights	154.73
Return per hen above cost of feed and lights	.57

The feed consisted of a mash having 150 pounds each of corn and oats, 100 pounds each of bran, shorts, and meat scraps, 50 pounds of wheat, and about 1 percent of salt; a scratch grain of 5 parts corn, 3 parts wheat, and 2 parts oats; and oyster shell plus 1,410 pounds of green feed. The average energy consumption per month was 7 kilowatt hours for 100 birds.

That the use of lights in the poultry house will increase egg production during the winter months has been demonstrated by various experimenters and by the experience of poultry growers. The Oregon Experiment Station[1] reports that in a test at that station quick-maturing pullets under lights produced 11.2 percent more eggs from October 1 to April 1 than the quicker-maturing pullets in pens with no lights. Less-mature pullets in lighted pens produced 21 percent more eggs from October 1 to April 1 than less-mature pullets in pens with no lights. Yearling hens produced 8.6 percent more eggs where lights were used. The New York College of Agriculture[2] reports that winter egg production has been stimulated so that in some instances 70 percent production has been obtained, that is, 70 eggs each day for each 100 birds in the flock.

[1]Ore. Agr. Exp. Sta. Bul. 231, page 27.
[2]N. Y. (Cornell) Exten. Bul. 90, page 3.

The results obtained in this brief study of poultry house lighting bear out the findings of similar studies in showing:

1. The lighting of poultry houses for egg production during the winter months when egg prices are high is good practice.

2. Satisfactory results have been obtained by turning the lights on in the morning to supplement daylight and give a 12- to 13-hour working day for the laying stock.

3. Adequate lighting is secured by using 40-watt lamps with proper shades spaced 10 feet apart and hung 6 feet from the floor.

4. The results secured by forcing breeding hens by use of lights thru the winter months is not sufficient to justify the practice.

5. The average energy consumption per month will vary from 6 to 10 kilowatt hours to 100 birds during the period lights are needed.

Incubating and Brooding

Some chicks are raised on practically every farm whether or not the principal interest is fruit, grain, livestock, or dairying. There is need for an incubator if the chicks are hatched on the farm, and usually some type of brooder is used. No special effort was made to interest the cooperators on the test line in this type of equipment, and no effort was made to obtain it on a loan basis. However, during the spring of 1928, 5 incubators and 11 brooders were purchased outright by the ten cooperators on the experimental line.

All the incubators and brooders were of the same make with the same type of overhead heating unit. A bimetal thermostat with a pilot light was used for regulating the temperature. Altho the incubators varied in size from 144-egg to 504-egg capacity, an energy rating of 300 watts was the same for all of them. The brooders were also rated at 300 watts.

The two incubators on which records were obtained were the 504-egg capacity. They were both located in an unheated basement where the temperature ranged from 45 to 60° F. The energy consumption for these incubators was relatively high owing to rather poor construction and to the low temperature of the room. For one incubator it was 79 kilowatt hours and for the other 92 kilowatt hours. Several degrees of variation were found in the temperature from the edge to the center of the egg tray. With better insulation there would not have been so much variation. The current was off for two hours during the test; the farmer noticed it, however, and covered the incubator with blankets and no damage resulted.

The results of these two tests with incubators would indicate that: (1) in selecting an incubator careful attention should be given to construction and to the insulation; (2) the thermostat should be thoroly tested and adjusted before the trays are filled; (3) a no-voltage or temperature alarm is a desirable feature; (4) attention should be

given to having the correct temperature at the egg level; (5) the incubator should be placed in a room having a relatively uniform temperature; (6) care should be taken to see that the right humidity is maintained in the box.

The brooders used measured 5 feet by 7 feet, were rectangular in shape, and were listed as having 500-chick capacity. In no case were more than 500 chicks placed in one brooder. In the brooder on which records were kept 500 chicks were placed. This brooder was operated for a period of one month (May) with a total energy consumption of 88 kilowatt hours. During the latter part of the period the current was turned off during the middle of the day when the weather was warm. The brooder was located in a colony brooder house. While in the houses with the electric brooders the temperature was not so warm some distance away from the brooder as in the coal-stove type of brooder, it was sufficiently warm immediately under the brooder. In a few instances the straw under the brooder became damp and required changing daily.

In selecting a brooder, care should be observed to see that the heating unit has sufficient capacity to maintain a temperature of 90° to 95° F. in all weather, that there is adequate ventilation and uniform distribution of heat, and that the brooder is large enough to avoid crowding (7 square inches of floor space under brooder has been recommended for each chick). It also seems desirable to have a no-voltage or temperature alarm on electric brooders.

Germinating Seed Corn

The demand of the farmer for better seed corn and for a method by which he can test his own seed corn for disease as well as germination led the Agronomy Department, in cooperation with the Farm Mechanics Department, to investigate the possibilities of an electrically heated germinator.

A report of preliminary studies of seed corn germination by these two departments appears in the Illinois Agricultural Experiment Station Annual Report for 1925-26 (page 37).

As a result of the preliminary work carried on in 1925-26 several special boxes using electricity for heat and electrical equipment for temperature control were built and tested. Observations were made on three germinators as a part of this study; two were small boxes used by individual farmers, and the other a large commercial size used by a cooperative seed company. All three of these germinators gave excellent results, the temperature being maintained in each of them at approximately 80° F.

The first box was tested on the farm of Cooperator 7 in 1926. It had a capacity of 8,000 kernels, or 1,600 ears. The average energy consumption per week was 34.4 and per bushel 2.15 kilowatt hours. Table 39 gives complete data on the three germinators.

The 1,600-ear capacity germinator box measured approximately 3 by 8 by 3 feet. It was made of well-matched lumber divided into two compartments. The insulation of the box from the outside wall was obtained by using 2 inches of oiled sawdust, one layer of Celotex, 2 inches of air space, and another layer of Celotex. The air space prevented moisture from being absorbed by the sawdust that might come thru from the inside of the box, thus doing away with the danger of the sawdust rotting and its insulating property being reduced. The inside of the box was painted with a lead-base paint to prevent moisture from being absorbed by the Celotex. However, an asphalt-base paint was found to be more practical for this purpose. Double doors were used to prevent heat loss at this point. The inside doors were provided with glass windows to permit the reading of the thermometer without loss of heat.

TABLE 39.—CORN GERMINATING TESTS WITH ELECTRIC HEAT UNITS, 1926-27

Germinator	Capacity of box	Size of heating unit	Total energy per week	Average energy per bushel tested	Cost per bushel
	ears	*watts*	*kw. hrs.*	*kw. hrs.*	*cents*
1[1].	1 600	400	34.40	2.15	6.4
2[2].	800	80	10.96	1.37	18.0
3[3].	14 000	5 000	395.70	2.82	7.6

[1]The box was located in an outbuilding, where heat was supplied by a coal stove in the day time. The temperature in the room was below freezing part of the time. The germinator was operated in February and March. The cost is based on 3 cents a kilowatt hour.

[2]The box was located in the basement of the residence and energy furnished by a unit electric plant. The cost is for the fuel and oil used per kilowatt hour. Germinator was operated for three weeks in April.

[3]Size of room, 10 by 15 by 10 feet. Located in seed house. Germinator operated during February and March. A baker's rate was secured for this application, making an energy charge of 2.7 cents a kilowatt hour.

The two chambers each contained four trays spaced 5½ inches apart. The trays were made up of 1-by-2-inch lumber with screen bottoms and filled with rotted sawdust and lime. Each tray had a capacity of 200 ears. The chambers were so constructed that when the trays were in place, the circulation of the air passed under and over each successive tray.

The heating apparatus consisted of four 100-watt light bulbs. Two bulbs were located as near the center of each chamber as possible. The temperature was controlled by a set of relays and a thermostat, the thermostat being located between the two chambers and about one-third the distance up from the bottom. A pan of water was located over the light bulbs in order to maintain proper humidity in the box.

Ventilation was provided by means of two ⅝-inch holes located at the bottom and near the center of the chamber. At this point the cold air comes in contact with the hottest part of the box, as the light bulbs are located in the center of each chamber and at the bottom. The outlets were near the top and at each end of the box.

Fig. 25.—Electrically Heated Seed Germinator

This 8-tray germinator was heated by energy from a unit plant. When located in a warm room, small germinators have been satisfactorily and economically heated in this way. The average energy used per bushel of corn tested was 1.37 kilowatt hours.

A small 8-tray 800-ear-capacity germinator was used by a farmer at Sidney, Illinois, and heated by electric energy supplied by a unit electric plant. This box was made from a plan furnished by the Farm Mechanics Department, University of Illinois. Fig. 25 is an inside

view of the germinator showing the details of the construction.[1] Two 40-watt light bulbs were used for heating elements. The weekly energy consumption varied as follows: first week, 13.7 kilowatt hours; second week, 11.8 kilowatt hours; and the third week, 7.4 kilowatt hours. The average energy used per bushel was 1.37 kilowatt hours. The cost of fuel and oil per kilowatt hour was 13.5 cents, 11.3 cents, and 14.8 cents respectively. On this basis the average cost of electricity to germinate 1 bushel of corn was 18 cents. It is evident from these data that it is economical and practical to heat a germinator with electricity from a unit electric plant if the germinator is located in a warm room.

Records were kept on a commercial-size electric germinator room constructed in a seed house at Tolono, Illinois. The dimensions of the germinator room were approximately 10 by 15 by 10 feet. It had a 14,000-ear capacity with provisions for a 20,000-ear capacity. This germinator room was equipped with 100 trays of 700-kernel capacity

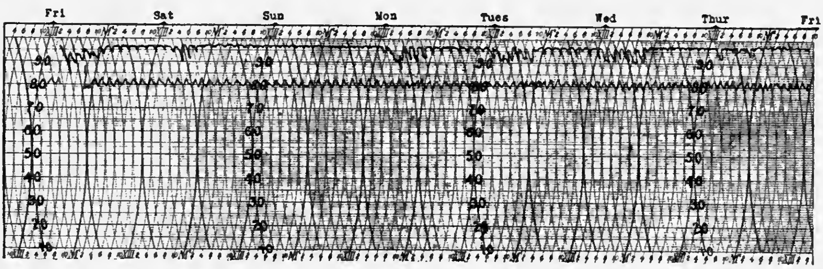


FIG. 26.—TEMPERATURE AND HUMIDITY RECORD IN GERMINATOR

By means of a thermostat, an even temperature of approximately 80° Fahrenheit and a practically saturated moisture condition may be maintained, which are essential for best results in the study of corn diseases with a germinator.

each, placed on racks on each side of a narrow passageway. Ten 500-watt bar space heaters were located below the trays, and water pans were placed just above the space heaters. No provision was made for ventilating the room. The temperature was regulated by a relay and bimetal thermostat. The thermostat was located about 6½ feet from the floor. A switch operated by a clock automatically changed the electrical connections so that the energy used during the day and during the night was recorded by two separate meters. The object of this arrangement was to benefit from a cheap early-morning rate.

Six men filled the germinator in five days. On the seventh day the trays that were loaded first were ready to be examined for disease and germination. The results were then read, recorded, and the trays re-

[1]Detailed plans of germinators may be secured from the Farm Mechanics Department at a nominal cost.

loaded. Thus the process of reading off and reloading trays was continuous over a period of two months.

A hygro-thermograph chart (Fig. 26) shows that the temperature was held practically constant at 80° F. The humidity was maintained between 95 and 98 percent. Over a period of two months the 89,040 ears of corn tested used 3,166 kilowatt hours of electrical energy. Allowing 100 ears to a bushel, the energy used per bushel was 2.82 kilowatt hours and cost approximately 8 cents a bushel.

The results of all these studies on germinators show that:

1. Electric germinators require minimum care in operation.
2. Regulation, including temperature and humidity control, is easily maintained.
3. Standard bar space heaters or heating coils give better results than light bulbs.
4. The operating cost of a large germinator is not high when a heating rate is provided.
5. A small-sized germinator should be located in a warm room in order to save energy and facilitate reading tests.
6. Proper humidity and constant temperature are the important factors affecting successful germination. Ventilation is not so important.
7. Sufficient capacity is provided by the ordinary unit electric plant to supply energy for heating the small size of germinator.

FIG. 27.—MACHINE USED FOR TREATING WHEAT FOR SMUT

Copper carbonate dust is recommended by the U. S. Department of Agriculture as the most satisfactory treatment known for controlling stinking smut in wheat. The energy consumption of this machine was 2.61 kilowatt hours per 100 bushels treated.

Treating Seed Wheat for Stinking Smut

"Millions of bushels of wheat," according to U. S. Department of Agriculture, "are lost annually because of smut." It is further stated that the market discounts for smutty wheat usually range from a few cents to 20 cents or more a bushel. The copper-carbonate dust or dry treatment is recommended by the Department as "the most satisfactory treatment known."[1]

One cooperator who manages a community seed house treated 2,821 bushels of seed wheat with a copper-carbonate dust in the fall of 1927, using a machine driven by a 1-horsepower electric motor. One man scooped the wheat from the wagon directly into the hopper of the dusting machine, from which it passed into the mixing chamber, and from there it was re-elevated into another wagon.

The capacity of the dusting machine was 40 bushels an hour when it was run at 50 revolutions a minute. The energy consumption was 2.61 kilowatt hours to 100 bushels treated.

BIGGEST PROBLEM IS TO DEVELOP A "PAY" LOAD

To obtain a satisfactory answer to the problem of rural electrification, it must be approached both from the standpoint of the farmer and from that of the power company. The important thing is for the power companies to provide an energy rate that is practical and economical for the farmer, thus encouraging sufficient use to justify extending lines.

Considerations in Cost of Farm Service

If a farmer or other isolated customer who cannot be served by existing city distribution systems uses only a limited amount of electric energy, the cost per unit must necessarily be higher than the cost in town, for the cost of getting the power to him is greater. A mile of distribution line in town generally serves thirty or forty customers, while in the country it serves only three or four. As most farmsteads are a quarter of a mile or more apart, a separate transformer must be provided for each, while in town one transformer may serve a dozen customers. In addition to the greater investment per customer there is in each transformer a continuous loss of energy, and this loss in the transformer makes up the greater part of the total loss on the line. Furthermore practically the same loss occurs regardless of the amount of current used. This is illustrated in Fig. 28, which is based on meter readings taken at the starting point of the experimental line—and which therefore give the total amount supplied on the line—and the total readings of energy as taken on the individual farms. Altho these readings were taken for two periods

[1] U. S. Dept. Agr. Dept. Circ. 394.

during which there was a wide difference in the amounts of energy used, the actual loss on the line was practically the same for both.

Large Use Essential for Low Rate

With the high cost of distributing electric power from a central service plant it is evident that a larger use for such power than that of the ordinary lighting customer must be developed if the costs of delivery, including losses, are to be spread over a large enough number of units to justify a rate which the farmer can afford to pay. The analysis made of the farmer's power problem and the results of tests reported in the preceding sections of this bulletin show that electricity may be put to many practical uses on the farm. Owing to the diversity of such uses it is clear that the farmer who uses considerable energy should be put in a different class from the ordinary domestic lighting customer in town or the ordinary lighting or power customer in the country. Some of the power companies recognize this fact and are providing a farm rate which encourages the farmer to find a large enough use for electricity in his business to enable him to secure it virtually on a wholesale basis rather than on a retail basis.

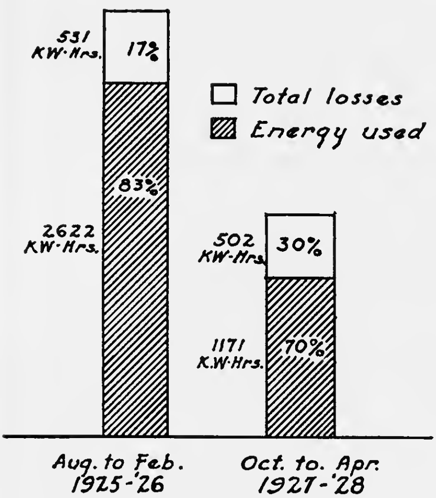


FIG. 28.—TOTAL LOSSES OF ENERGY ON EXPERIMENTAL LINE DURING TWO SIX-MONTHS' PERIODS

The energy losses in transformers are practically constant irrespective of the quantity of energy used. On some electric distribution lines where only small quantities of electricity are used, the total losses including line and transformer losses are about as great as the total consumption.

That many farmers are willing to pay a considerable sum in order to have electricity for lighting their homes is evidenced by the large number who have invested in farm lines and who have installed unit electric plants primarily for this purpose. By additional use, complete electric service is made available at relatively little additional cost. The effect of greater use on the unit cost of electricity to the ten cooperators during the first six months of 1928 is shown in Table 40. These costs are based on the rates then in force. The cost per kilowatt hour of energy for the ten customers ranged from 13.6 cents for those using the least amount to 5.1 cents for those using the greatest amount. The monthly energy consumption ranged from 42 kilowatt hours to 278 kilowatt hours.

TABLE 40.—UNIT COST OF ELECTRICITY TO THE TEN COOPERATORS ON THE EXPERIMENTAL LINE, BASED ON RATES IN FORCE AND AVERAGE MONTHLY CONSUMPTION DURING FIRST SIX MONTHS OF 1928

Cooperator	Average energy used monthly	Average cost per month	Cost per kw. hr.
	kw. hrs.		*cents*
1[1]	42	$ 5.72	13.6
2	278	14.29	5.1
3	136	10.03	7.4
4	178	11.29	6.3
5	133	10.00	7.5
6	171	11.08	6.5
7[1]	148	11.28	7.6
8[1]	60	6.62	11.0
9	144	10.27	7.1
10	246	13.33	5.4

[1]Cooperators 1, 7, and 8 each had an investment of $360 in the line. In order to errive at their total expense for electricity, $1.80 was added to the monthly bill of aach. This covered interest at the rate of 6 percent annually on the amount of their investment.

A number of the power companies serving about 75 percent of the farming area of the state have adopted a farm rate which is designed

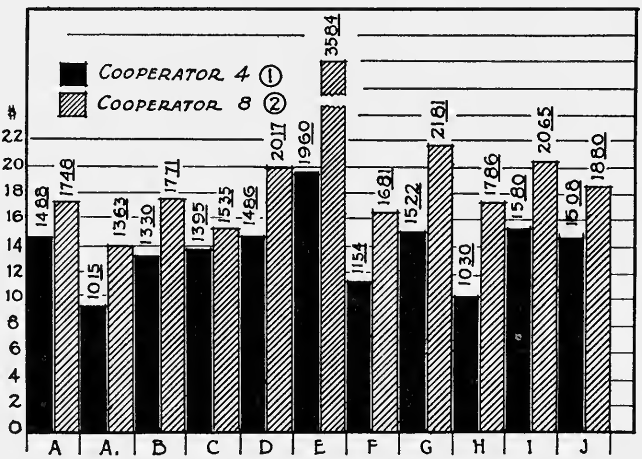


FIG. 29.—EFFECT OF DIFFERENT RATES OFFERED BY DIFFERENT POWER COMPANIES

The average monthly bills of two cooperators on the test line were figured according to the rates offered by 10 Illinois power companies in May, 1927. According to the lowest rate (A_1) the cost of electric power on the farm of Cooperator 4 would have been $10.15. In this household were five persons. Thirty-two kilowatt hours were used for light, 4 for heat, and 104 for power, a total of 140. Cooperator 8 had a family of four and used 256 kilowatt hours: 26 for light, 139 for heat. and 91 for power, and the cost under rate A_1 was $13.63.

to encourage use and is satisfactory for the customer who is in a position to use complete electric service. This rate was submitted to the farmers on the experimental line, and eight of the ten who were using a rather large amount of energy accepted it as a better rate than the one under which they were being served. The bar designated as A_1 in Fig. 29 shows the cost of service under this new rate in comparison with rates of other companies.

Some of the principal factors that limit the use of electric power in carrying out the many processes of farm production are: (1) seasonal use of machinery; (2) varying power requirements; (3) difficulty of adapting present farm equipment to electric power; (4) present methods used in many farm operations; (5) lack of satisfactory methods for applying electric power to field operations; (6) cost of electrical equipment. In spite of these limitations the ten farmers on the test line are using several times as much electric energy each month as the average farm customer or the average city lighting customer.

ESSENTIAL FEATURES OF FARM RATES

From the results secured on the experimental line with the ten cooperating farmers and from studies of other rates, it is evident that the essential features of a satisfactory rate for farm electric service can be summed up as follows:

1. It should be fair and equitable alike to large and small customers.
2. It should be easily understood.
3. It should encourage the use of electricity.
4. Provision should be made for financing the building of the line by the company, or allowing the customer to finance lines as an optional plan.

Flat Rate Penalizes Larger Consumer

To meet the high fixed costs of extending electricity to farmers, some power companies have established a high kilowatt-hour charge which applies regardless of the amount of energy used. As a result the farmer who uses a large amount of electric energy is penalized and the farmer who uses only a little is favored, for once the fixed costs are met the cost of supplying additional energy is relatively low. Under such a rate, if one farmer were to use twice as much energy as his neighbor, his bill would be twice as large, yet the cost to the power company for supplying the larger amount would be only a little more than for the smaller amount. Such a schedule discourages many farmers from using electric service for anything but lighting.

A farm rate will pay the power company a proper return on the investment when a reasonable amount of service is used by the farm-

er, and that will supply all additional energy at a price commensurate with its cost, will encourage the use of electric energy on the farms of Illinois.

Lack of Uniform Rates Cause of Dissatisfaction

There has been and still is a wide variation in the farm rates of different companies as well as in the charges made on the same farm for current for different purposes, such as light, heat, and power. The farmer cannot understand why he should not have one rate for the energy that comes over one set of wires at the same time of day, whether it is used for lighting or for several other uses, or why there should be so much difference between his monthly energy charge and that of another farmer who is served by another company.

To show the variation in rates charged by different companies, the bills for one month for two of the cooperating farmers on the experimental line were figured by ten different companies, with the result shown in Fig. 29. For 256 kilowatt hours, the amount of electricity used by Cooperator 4 would have cost $35.84 if served by Company E. If served by Company C, in another part of the state, the cost would have been $15.85. If supplied under the new rate, which was slightly changed April 1, 1929, the cost would have been $13.18 (see Fig. 29, Company A1). Under this rate all the energy is supplied thru one meter, the first 150 kilowatt hours costing $10 for a 3-kilowatt transformer installation and all additional energy 3 cents a kilowatt hour. Under this plan the farmer guarantees to use ten dollars' worth of energy monthly and the company finances the line up to $450 a customer.

Financing the Line

A rate plan under which the building of the line is financed by the power company seems advisable if farmers are to be encouraged to make larger uses of electric energy. The cost to the average farmer for fixtures for his house and for wiring the buildings is $200 to $300. If in addition to this he has to invest $400 or $500 in building a line, he has little ready money left to invest in equipment; and as a result, he is unable to realize the full advantage of central power station service, yet the cost of serving him will be nearly as great as the cost of furnishing service to the farmer with considerable equipment. Thus the farmer with little equipment gets less for his money and is more likely to become dissatisfied.

Potential Farm Load Worth Consideration of Power Companies

Relatively few power companies have developed a rate for farm service that takes into consideration the fact that there is a fairly large potential use for electricity on the farm. Where electricity has

been made available many farmers have made only a limited use of it. With recognition of its possible uses and equitable adjustment of rates, power companies can greatly extend their business and farmers will be enabled to solve many of their labor and living problems.

APPENDIX

One Year's Results With Five Unit Electric Plants[1]

The unit electric plant makes it possible for many farms of the country to have electricity that cannot be reached economically by power lines. Such a plant, however, does not have sufficient capacity to supply complete service for power purposes. Its use is limited to lighting and to the operating of household appliances and small motors. Nevertheless a study of rural electrification would be incomplete without some data on this type of electrical equipment.

Five Champaign county farmers who were using unit electric plants from which to obtain power cooperated with the University for one year by keeping records of all fuel and oil used. Meters were installed at each farm to determine the actual energy produced each month by each of these five plants.

The equipment operated by electrical energy from the unit plants located on these five farms was as follows:

- 3 washing machines
- 3 separators
- 3 soft-water pumping systems
- 3 radios
- 1 deep-well pumping system
- 1 refrigerator
- 1 vacuum cleaner
- 1 churn
- 2 motors of ¼ horsepower

Eleven to 20 lights were used in each of these five farm houses, or an average of 15 per house. The number of lights in outbuildings was not recorded, but there were not over 6 to 8 to a farm.

The yearly and monthly energy consumption for each of the five farms are given in Table 41.

On four of the farms the average energy consumption was 16.9 kilowatt hours and on the fifth farm 67.7 kilowatt hours. This higher consumption was due largely to the use of an electric refrigerator and a deep-well pump operated by an electric motor. The energy required for refrigeration made up 62.5 percent of the total amount used on the fifth farm, and the energy required for pumping water ranged from 1.6 to 33.4 percent of the total amount used on all farms, as determined by individual meters.

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[1]Data secured by R. C. Kelleher, formerly First Assistant in Farm Mechanics.

TABLE 41.—YEARLY AND MONTHLY CONSUMPTION OF ENERGY FROM FIVE UNIT ELECTRIC PLANTS[1]

Cooperator	Energy used per year[1]	Energy used per month
	kw. hrs.	*kw. hrs.*
1.	143	11.90
2.	165	13.75
3.	189	15.75
4.	318	26.50
Average for four farms.	203	16.90
5.	813[2]	67.70[2]

[1]Computed from records extending over approximately eleven months.
[2]Farm 5 used a refrigerator and also a motor on a deep-well pump. This raised the yearly energy consumption considerably above the other four farms, where such appliances were not used.

Four of these unit plants were operating on kerosene. They used an average of 43.2 gallons of kerosene and 2.45 gallons of lubricating oil per 100 kilowatt hours generated. With kerosene at 12 cents a gallon and oil at 66 cents, the cost of kerosene and oil amounted to 6.8 cents a kilowatt hour.

TABLE 42.—COMPUTED YEARLY COST OF OPERATION, AND THE UNIT COST PER KILOWATT HOUR GENERATED BY UNIT ELECTRIC PLANTS OF DIFFERENT ASSUMED ENERGY OUTPUTS, 1925-26

Energy output (kw. hrs.)						
Monthly	10	20	30	50	70	100
Yearly	120	240	360	600	840	1 200
Assumed life of engine and generator, years	17	14	9.5	8	7	6
Assumed life of battery, years	7.5	6.5	5.25	4.5	4	3.5
Interest, $520 at 6 percent	$31.20	$31.20	$31.20	$31.20	$31.20	$31.20
Cost of kerosene and oil at 6.8 cents a kw. hr.	8.15	16.30	24.45	40.80	57.00	81.50
Cost of repairs	1.75	2.50	3.75	5.00	6.00	7.00
Cost of labor for making repairs	1.75	2.50	3.75	5.00	6.00	7.00
Depreciation on engine and generator, value $320[1]	11.65	15.20	25.90	32.40	38.20	45.90
Depreciation on battery, value $200[1]	21.85	26.00	33.50	40.00	45.80	52.90
Total annual cost	$76.35	$93.70	$122.55	$154.40	$184.20	$225.90
Cost of energy per kilowatt hour	$ .64	$ .39	$ .34	$ .26	$ .22	$ .19

[1]Depreciation $= \frac{cr}{(1 + r)n - 1}$ in which c = cost of renewal; r = rate of interest; and n = life of plant in year. As a basis for determining the depreciation, the life of the equipment was arbitrarily assumed. Operating costs are based on actual costs on farm-operated machines.

The plant operating on gasoline used 55 gallons of gasoline and 13 gallons of oil to 100 kilowatt hours. With gasoline at 18.6 cents a gallon and oil at 89.5 cents, the cost of gasoline and oil was 21.9 cents a kilowatt hour. This plant was in poor mechanical condition and was leaking oil.

Table 42 shows the computed annual expense and cost of energy per kilowatt hour for farm electric plants having different monthly outputs of energy. Table 43 shows a comparison between the computed cost of energy per kilowatt hour from 32-volt farm electric plants and energy cost to farmers on the experimental line.

TABLE 43.—COMPARISON OF COST OF ENERGY OBTAINED FROM FARM ELECTRIC PLANTS AND COST FROM CENTRAL STATION PLANT BASED ON RATE IN EFFECT IN A LARGE PORTION OF ILLINOIS IN 1929

(Cents per kilowatt hour)

Energy used per month	Cost from 32-volt farm plant (computed in Table 42)	Cost from central station plant[1]
kw. hrs.	*cents*	*cents*
10	64	50
20	39	25
30	34	17
50	26	13
70	22	11
100	19	10
150	..	6.66
250	..	5.20
350	..	4.57

[1]Based on optional power and light rate for amounts less than 100 kilowatt hours per month for a seven-room house where farmer invests in the line: First 16 kilowatt hours at 12 cents net; next 32 kilowatt hours at 8 cents net, and all over at 5 cents net. Minimum charge of $3 per month and no motor larger than 1 horsepower can be used. A $2 interest charge per month based on a $400 line investment was allowed. When company invests in the line the farmer pays $10 for the first 150 kilowatt hours and 3 cents a kilowatt hour for additional energy which may be used for lighting, heating, and power service. In this table the energy costs for amounts of energy of 100 kilowatt hours and more are calculated on the $10 rate.

On the basis of these figures the energy cost per kilowatt hour for energy delivered from a unit electric plant is higher than for energy delivered by a central service station. If central station power can be obtained at a reasonable cost, it undoubtedly is better to choose it than to install a unit electric plant since greater power and heat service can be provided at less expense. The unit plant, however, can render great service where central station service is not available, as it provides the power for most of the conveniences found in the city home.

Definition of Electrical Terms

Energy is the capacity for doing work. Any body or medium which is of itself capable of doing work is said to possess energy. There is a definite nu-

merical relation between different sorts of energy. In electrical units, it is expressed in watt hours or kilowatt hours.

Power is the rate of doing work. The customary unit is the watt and the horsepower.

Ampere is the rate of flow of electricity. It is comparable to the amount of water flowing thru a pipe at a given time.

Volt is the unit of electrical pressure. It may be likened to the pressure in a water pipe. The greater the pressure or voltage with the same flow of electricity, the greater the energy.

Watt is the electrical unit of power. It is equal to the electrical pressure in volts multiplied by current in amperes.

1 **Kilowatt** is equal to 1,000 watts. A kilowatt hour is equivalent to the use of 1,000 watts for one hour. It is the common unit used in measuring electrical energy.

1 **horsepower** is the power required to raise 33,000 pounds one foot in one minute, which is approximately equivalent to the work performed by one horse.

1 horsepower = 746 watts (approximately ¾ kilowatt)
1 kilowatt = 1⅓ horsepower

Work Performed by One Kilowatt Hour

One kilowatt hour will operate the following equipment approximately the length of time indicated:

	Hours
Vacuum sweeper	6¾
Hand iron	1¾
Curling iron	47½
Table stove	2
Toaster	1¾
Grill	2¼
Percolator	2½
Heating pad	15½
Dish washer	4
Battery charger	10
Fan	22¼
Light bulb (50-watt)	20
¼ horsepower motor	4
Sewing machine	13

Energy Consumption for Various Farm and Home Operations as Determined by State Experiment Stations and Other Agencies

Apple Grading. Capacity of the machine tested, 25 boxes per hour; operated by ½-hp. motor. Energy requirements for each 100 bu. of apples graded, .5 to 1.5 kw. hrs., or average of 1 kw. hr. Machine is justified if grower has 4,000 to 6,000 bu. apples to be graded. (Ind. Agr. Exp. Sta. Circ. 134 and C.R.E.A. Bul., Vol. 4, No. 1, p. 104)[1]

Battery Charging for Radio. Kw. hr. consumption per month dependent on type of radio and on amount of time used. Average per month noted was 7.78 kw. hrs. (Kans. Engin. Exp. Sta. Bul. 21, p. 25)

[1]Data in this reference were obtained largely from preliminary reports of state agricultural experiment stations published by National Committee on Relation of Electricity to Agriculture.

Bone Grinding. Grinder with capacity of 100 to 150 lbs. per hour operated by 5-hp. motor used 1.1 kw. hrs. per 100 lbs. bone ground. (C.R.E.A. Bul., Vol. 4, No. 1, p. 81)

Bottle Washing. Single brush washer with ⅙-hp. motor used 2.2 kw. hrs. per month when 300 bottles were washed each day. (N. H. Agr. Exp. Sta. Bul. 228, p. 40)

Brooding. Black heat type brooder averaging 665 chicks used .47 kw. hr. per chick during period of 40 days. Radiant type brooder of practically same capacity averaged 1.55 kw. hrs. per chick during period of 50 days. (Cal. Agr. Exp. Sta. Bul. 441, p. 39)

Bulb Cooking. Machine with capacity of 150 lbs. bulbs driven by ¼-hp. motor and with connected load, including heating element and motor, of 2,186 watts used 2 kw. hrs. for each 100 lbs. bulbs cooked. (C.R.E.A. Bul., Vol. 4, No. 1, p. 112)

Bulb Grading. Bulb grader operated by ¼-hp. motor graded 177 lbs. bulbs in 6½ minutes. Power required was negligible. (C.R.E.A. Bul., Vol. 4, No. 1, p. 111)

Butter Making. Churn with ¼-hp. motor used .99 kw. hrs. to churn 100 lbs. butter. (P. 426, this bulletin)

Clothes Washing. Operation required 1.69 kw. hrs. per month for average family of 4.4 persons; type of machine not stated (C.R.E.A. Bul., Vol. 4, No. 1, page 13). With cylinder washer 3.09 kw. hrs. per month were required for family of 5.34 persons; with single-tub dolly-type washer 2½ kw. hrs. per month for family of 4, and with double-tub dolly 1.31 kw. hrs. (Kans. Engin. Exp. Sta. Bul. 21, p. 23)

Concrete Mixing. Concrete mixer with ½-hp. motor used .4 to .5 kw. hr. to mix 1 cu. yd. of concrete. (C.R.E.A. Bul., Vol. 4, No. 1, p. 114)

Cooking. Average of 32.5 kw. hrs. per person per month were used in cooking with electric range. Total energy per month for average-sized family of 5.9 persons was 191.1 kw. hrs. (P. 416, this bulletin)

Corn Husking and Shredding. An 8-roll husker-shredder with 10-hp. motor used 20 kw. hrs. to husk 100 bu. and shred stalks. (C.R.E.A. Bul., Vol. 4, No. 1, p. 88)

Corn Shelling. Hand-feed sheller with ½-hp. motor used 8 kw. hrs. for each 100 bu. corn shelled. Two-hole power sheller with ½-hp. motor used 2 kw. hrs. per 100 bu. shelled. (C.R.E.A. Bul., Vol. 4, No. 1, p. 87)

Cream Separating. Separator operated by ⅙-hp. motor used .047 kw. hrs. to separate 100 lbs. milk, using average energy consumption of 1.31 kw. hrs. per month. (P. 451, this bulletin)

Dairy Sterilization. A 4-can sterilizer with connected load of 3,000 watts required 3.78 kw. hrs. for one sterilization of equipment used with a 22-cow herd. (C.R.E.A. Bul., Vol. 4, No. 1, p. 48)

Dish Washing. Dish washer with ¼-hp. motor used average of 2.2 kw. hrs. energy per month. (P. 426, this bulletin)

Ensilage Cutting. Cutter with 15-hp. motor used 1.72 kw. hrs. per ton of ensilage cut (see p. 436, this bulletin). A 13-inch cutter with 5-hp. motor used .615 kw. hr. per ton when corn was fed into cutter in bundles. Same cutter with 5-hp. motor used .85 kw. hr. per ton when corn was fed in loose form. Rate of feeding during second test was about one-half the first. ("Report on Silo Filling With a Five-Horsepower Motor," F. L. Fairbanks, Cornell University)

Feed Cutting (Green). Root cutter operated by 1-hp. motor used 2 kw. hrs. per 1,000 lbs. of roots cut. (C.R.E.A. Bul., Vol. 4, No. 1, p. 81)

Feed Grinding. An 8-inch burr mill with 20-hp. motor used average of .339 kw. hr. per 100 pounds shelled corn when ground medium-fine. Average of .772 kw. hr. was required per 100 lbs. of oats when ground medium-fine. A 6-inch burr mill with 5-hp. motor used average of .449 to .662 kw. hr. per 100 lbs. of sappy ear corn when corn was ground medium-fine. One hundred lbs. of wheat ground fine used .410 kw. hr.; 100 lbs. of soybeans ground medium-fine, .720 kw. hr.; and 100 lbs. of shelled corn ground fine, .440 to .660 kw. hr. (see p. 443, this bulletin). A 6-inch burr mill with 1-hp. motor used .274 kw. hr. per 100 lbs. of shelled corn when corn was ground medium-fine. (Iowa C.R.E.A. Bul., Jan. 6, 1926)

Fly Control. A screen door fly electrocutor with connected load of 8 watts used 5 to 13 kw. hrs. per month. (C.R.E.A. Bul., Vol. 4, No. 1, p. 53)

Food Mixing. Machine operated by 1/10-hp. motor required .5 to 1.2 kw. hrs. per month for all operations. (P. 419, this bulletin)

Grain Elevating. Drag elevators operated by 5-hp. portable motors used average of .423 kw. hr. to elevate 1,000 bu. of corn to height of 1 foot. (P. 432, this bulletin)

Grain Threshing. A 22" x 36" threshing machine operated by 3 motors—10-hp., 3-hp., and 1½-hp.—used 11.1 kw. hrs. per 100 bu. of oats threshed and 26.5 kw. hrs. per 100 bu. of wheat threshed. (C.R.E.A. Bul., Vol. 4, No. 1, p. 117)

Hay Baling. Baler operated by 5-hp. motor used 1.62 kw. hrs. per ton of hay baled. Bales averaged 75 lbs. each. (C.R.E.A. Bul., Vol. 4, No. 1, p. 90)

Hay Chaffing. Ensilage cutter with 30-hp. motor used 3.34 kw. hrs. to chaff 1 ton of alfalfa hay and 5.7 kw. hrs. to chaff 1 ton of soybean hay. (Pp. 438 and 441, this bulletin)

Hay Grinding. An 8-inch burr mill equipped with cutter head and 20-hp. motor used 18.6 kw. hrs. to grind 1 ton of alfalfa hay and 29.2 kw. hrs. to grind 1 ton of soybean hay. (Pp. 438 and 440, this bulletin)

Hay Hoisting. Hoist operated by 3-hp. motor required .32 kw. hr. per ton of hay. Another hoist operated by 5-hp. motor required .48 kw. hr. per ton of hay hoisted to 45 feet. (C.R.E.A. Bul., Vol. 4, No. 1, p. 89)

Hot-Bed Heating. A hot bed 6' x 3' in size had a connected load of 150 watts. Sixty-three kw. hrs. were required to heat hot bed for periods of 7 weeks, with average outside temperature of 40° F. (Wash. Agr. Exp. Sta. Bul. 219, p. 11)

Incubation. Three incubators with capacity of 150 eggs and less used average of 179 kw. hrs. for each 1,000 eggs; 7 with 151 to 300 egg capacity used average of 134 kw. hrs.; 3 with capacity of 301 to 600 eggs averaged 123 kw. hrs.; 5 with 1,000 to 1,500 egg capacity, 145 kw. hrs. One 6000-egg incubator used 32 kw. hrs. per 1,000 eggs incubated, and three with 13,000 to 15,000 egg capacity used average of 22.8 kw. hrs. (C.R.E.A. Bul., Vol. 4, No. 1, p. 73)

Ironing by Hand. Energy requirement for family averaging 4.25 persons was 5.42 kw. hrs. per month. Average kw. hr. consumption per person per month was 1.27 (Kans. Engin. Exp. Sta. Bul. 21). Additional data on hand and machine ironing are given on p. 412, this bulletin).

Kitchen Ventilation. Kitchen ventilating fan required less than 10 kw. hrs. per month. (C.R.E.A. Bul., Vol. 4, No. 1, p. 13)

Lighting Barn. Three barns with average of 19 outlets per barn used 7.9 kw. hrs. per barn per month. (N. H. Agr. Exp. Sta. Bul. 228, p. 38)

Lighting House. Average monthly energy consumption per house with average of 39 outlets each, 7 families, was 34.6 kw. hrs. (N. H. Agr. Exp. Sta. Bul. 228, p. 32)

Lighting Poultry House. Energy requirement from Nov. 15 to Mar. 31 was 3 to 5 kw. hrs. per month for 100 birds. (N. Y. Cornell Agr. Exp. Sta. Exten. Bul. 90)

Milking. Pipe-line machine with ¾-hp. motor used 27.4 kw. hrs. per month per herd of 10 cows. (P. 447, this bulletin)

Oats Hulling. Machine with 5-hp. motor used 9.17 to 17.2 kw. hrs. for each 100 bu. of oats hulled. (P. 446, this bulletin)

Oats Sprouting. Connected load for homemade tray-type oat sprouter was 440 watts. To sprout 10 pounds of dry oats daily required 158.4 kw. hrs. per month. Connected load was increased to 880 watts during cold weather; amount of energy used would be increased in approximately same proportion. (N. H. Agr. Exp. Sta. Bul. 228, p. 43)

Orchard Spraying. Stationary spray units with motors ranging in size from 1½ to 10 hp. used average of 47.4 kw. hrs. per acre for average of 7½ sprays per year. Area sprayed per unit ranged from 4 to 35 acres. (Wash. Agr. Exp. Sta. Bul. 212, p. 41)

Paint Spraying. Machine operated by 1½-hp. motor required average of .72 kw. hr. for each 100 square feet of surface painted. This test was on an old barn which was painted twice. (P. 455, this bulletin)

Potato Grading. Grader with capacity of 350 bu. per hour operated by ½-hp. motor required 1 kw. hr. to grade 700 bu. Machine saved labor of one man. (Giant Power Survey of Pennsylvania, February, 1925)

Refrigeration (Household). Average kw. hr. consumption per refrigerator for 47 refrigerators per month on yearly basis was 46 kw. hrs. Average size of box was 10.9 cu. ft. (C.R.E.A. Bul., Vol. 4, No. 1, p. 16). For 10 refrigerators in Illinois average monthly energy requirement was 41.9 kw. hrs. (see p. 420, this bulletin)

Refrigeration (Milk). Monthly energy requirement for entire year's operation ranged from 26.4 to 48.3 kw. hrs. per 100 quarts of milk stored daily. (N. H. Agr. Exp. Sta. Bul. 233, p. 20)

Seed Germinating. With 1,600-ear capacity germinator, 800-watt connected load, 34.4 kw. hrs. were required to operate germinator thru one germinating period. (P. 462, this bulletin)

Seed Grading and Cleaning. With grader operated by 1-hp. motor, 4 kw. hrs. were required per 1,000 bushels of grain graded and cleaned. (C.R.E.A. Bul., Vol. 4, No. 1, p. 91)

Sheep Shearing. A 13-tooth clipper operated by ½-h.p. motor used 2.5 kw. hrs. for each 100 sheep sheared. Time required for one sheep was 4.34 minutes. (C.R.E.A. Bul., Vol. 4, No. 1, p. 113)

Trucking. Truck equipped with 42-cell battery, driven average of 14½ miles a day, used 87.5 kw. hrs. for each 100 miles, or 391 kw. hrs. per month. (C.R.E.A. Bul., Vol. 4, No. 1, p. 71)

Water Heating. A 15-gallon thermos-bottle heater with 3000-watt connected load used 293.6 kw. hrs. per 1,000 gallons of water heated. (P. 408, this bulletin)

Water Pumping. Average energy requirement to pump water from cistern reported by five states as 1.81 kw. hrs. per month. Average energy requirement per month per family for domestic water supply for 11 families, water pumped

from a depth of less than 25 feet, was 4.8 kw. hrs. Average energy requirement per month per farm for 16 farms for farm water supply from deep wells was 32 kw. hrs. (C.R.E.A. Bul., Vol. 4, No. 1, p. 34)

Wood Sawing. Buzz saw with 3-hp. motor used 1.1 kw. hrs. to saw cord of wood into 18-inch lengths. Same outfit used 2.4 kw. hrs. to saw cord of wood in 12-inch lengths. (C.R.E.A. Bul., Vol. 4, No. 1, p. 114)

SUMMARY

1. The distribution of electric power in Illinois has reached a point where many areas remote from the centers of population have electric service available.

2. This study differed from similar projects in which individual items of equipment were studied, in that a number of pieces of equipment were installed on each farm, and the use, the value to the farmer, and the energy requirement were determined in relation to other types of equipment on the same farm.

3. The cost of wiring and fixtures, and the cost of electrically operated equipment incident to the use of electric service are two factors which limit its use on the farm.

4. The farm home with its need for better lights, a convenient source of heat for cooking, water supply under pressure, and power for many other appliances offers a wide field for the application of electricity.

5. Those farms on the experimental line making the greatest use of electricity use more in the home than in production work. The kitchen range and the household refrigerator are the pieces of equipment consuming the most electricity.

6. The use of electrically operated household equipment results in a saving of time for the housewife, and the work in the home is made easier.

7. The type of farm and the specific enterprises carried out on the farm determine the applications and the extent to which electric service can be used in production work.

8. The fact that approximately 50 percent of the labor of the farm is spent about the farmstead suggests the possibilities of the use of electricity for light and power to make this labor more effective (see Table 11, page 400).

9. The results of tests demonstrate that electricity is an economical and practical form of energy for operating milking machines, cream separators, seed germinators, feed grinders, ensilage cutters, incubators, brooders, pumps, and portable motors for operating grain elevators, wood saws, feed mills, and other power-driven equipment on the farm.

10. The ten cooperating farm customers on the experimental line are using about five times as much electric energy as the average city lighting customer.

11. Since there are few customers to a square mile in the general farming area and the cost of distribution is high, the power companies must furnish electric energy at a rate that will make it profitable for the farmers to use it in large quantities.

12. The results of this study indicate that many farmers can make sufficient economic use of electric energy to justify power companies in building farm lines.

13. The rate first tried on the experimental line, making it possible for the farmer to get complete service without financing the line, has been put into effect in at least 75 percent of the area of the state in which electric energy is now available.

14. The unit electric plant furnishes sufficient energy for lighting and for operating small motors and small appliances. The cost of energy from the unit plant is greater than from the central station plant when served under existing rates in effect on the experimental line (see page 473).